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Planispheric Astrolabes from the National Museum of American History

Sharon Gibbs
with George Saliba

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ABSTRACT

Gibbs, Sharon, with George Saliba. Planispheric Astrolabes from the National Museum of American History. *Smithsonian Studies in History and Technology*, number 45, 231 pages, 130 figures, 23 tables, 1984.—This monograph describes via catalog entries and comparative analysis what has for many years been one of the five largest collections of planispheric astrolabes in the world. Until 1974, when seven instruments that had been on long term loan were returned to their owner, the National Museum of American History of the Smithsonian Institution preserved 48 examples of functioning astrolabes. This is the first detailed discussion of all 48, together referred to as the collection. The majority of the instruments, including the seven no longer on loan to the museum, once were part of the collection of Samuel Verplanck Hoffman of New York City.

An introductory chapter, using words and drawings, describes the basic elements of a planispheric astrolabe, thereby introducing terms that appear frequently in later sections. The section "Historical Perspective" emphasizes the information conveyed by the makers' names and dates inscribed on instruments in the collection. It places this information in the larger context of the history of the development of the astrolabe. Each of the functional elements incorporated into the astrolabes in the collection is discussed in detail in a chapter devoted to comparative analysis. That section illuminates distinctions between European instruments and instruments made in India or in the Muslim world. In each section, the basic features of a functional element are described and any remarkable treatments of these features are noted. In addition, the traditional function of each element is specified, relying on instructions for its use prepared by Mashaʾallah, al-Biruni, or Chaucer. Photographs illustrate each section.

Complementing this comparative analysis is an illustrated catalog of the collection. It includes transcriptions and translations of inscriptions that appear on the instruments. Appended to the catalog are two sections that present and discuss the information conveyed by the gazetteers incorporated into many Muslim astrolabes and the star networks (or retes) included on all complete astrolabes in the collection. Finally, a third appendix describes the process used to prepare the ecliptic circle component of the astrolabe's star network. In doing so it conveys basic information about the construction of a planispheric astrolabe.

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Foreword

The astrolabe of Islam was a traveler's instrument. Whether the owner was an astrologer, astronomer, geographer, surveyor, religious or civil official, his planispheric astrolabe was portable and designed for use across several latitudes. Travel has also been an important factor in accounting for the popularity of astrolabes and pseudo-astrolabes as collectors' items in recent decades. Americans and Europeans visiting the shop of an instrument maker in Isfahan have been attracted by the esthetic appeal of the twentieth century object, just as international visitors in the antique store of a scientific instrument dealer in Paris or London have been drawn by the mathematical and scientific elegance of the beautifully crafted, traditional, functional object.

Curiosity about astrolabes is not a recent phenomenon, however. Several nineteenth-century studies of individual instruments attest to the interest taken by philologists and other scholars in these artifacts, which came to be treated as source documents for the study of Islamic civilization and its impact on Western learning. Numerous hobbyists and art collectors likewise acquired astrolabes out of interest in history, science, or art long before the ownership of a single such object (to be displayed in the living room) became a desirable goal in itself. Indeed, most of the major known private collections date back to the last century.

The collection of astrolabes in the National Museum of American History reflects long-standing American interests in the subject. It was an American traveler in Europe who purchased the first astrolabe for the United States National Museum in 1888. He was Samuel P. Langley (1834–1906), noted contributor to the study of solar radiation and the early history of flight, and third Secretary of the Smithsonian Institution. He authorized purchase of this astrolabe (CCA No. 2569), along with several other scientific instruments, from Raoul Heilbrunner in Paris. Subsequent astrolabes came from owners representing a variety of economic classes, who had acquired the objects in the nineteenth and twentieth centuries, either as single objects of curiosity or in the course of building a collection. Among these owners were Americans of colonial ancestry as well as recent immigrants. Aside from purchases made possible in large part by corporate donors such as International Business Machines Corporation, the objects in the collection came through the generosity of individual donors. We owe particular gratitude to E. Nagel, N. Grossman, Lessing J. Rosenwald, and an anonymous donor. The bulk of the astrolabes in the National Museum of American History belonged to the Samuel V. Hoffman collection, however, and came to the Smithsonian Institution through the cooperation of his children, the late Edgar and Margaret Hoffman.

Samuel Verplanck Hoffman (1866–1942) of New York City was the son of Eugene Augustus Hoffman, the dean of the General Theological Seminary, and the grandson of Samuel Verplanck Hoffman, a well-to-do New York merchant and insurance executive. The family had considerable holdings, including a large amount of real estate in Manhattan, which S.V. Hoffman managed. A graduate of Stevens Institute of Technology, Hoffman had done graduate work at Columbia and, more intensively, at the Johns Hopkins University, where he studied astrophysics and chemistry. By the turn of the century, he had acquired a reputation as a knowledgeable collector, and gave advice on the subject to the Smithsonian Institution. Sections from his sundial collection were loaned to the Smithsonian on several occasions. He was closely affiliated with the New York Historical Society, serving as its president from 1903 to 1913, and as a trustee from 1913 until 1942.

Samuel V. Hoffman bequeathed his fine library on early mathematical and astronomical instruments to the New York Historical Society, along with most of his collection of sundials, the mariner's astrolabe associated with Champlain, and seven planispheric astrolabes. He bequeathed the major part of the astrolabe collection and other assorted pieces to his children, who decided in 1959 that these objects should become part of the National Collections entrusted to the Smithsonian Institution. It is this collection that forms the core of the National Museum of American History's astrolabe holdings. The present study also includes the seven planispheric astrolabes that had been given to the New York Historical Society, since these were loaned to the Smithsonian Institution and displayed in this Museum until the New York Historical Society sold them at auction in 1975. They are identified by the NMAH numbers 322327, 322458–322461, 322463, and 322464 (CCA Nos. 65, 4, 58, 42, 55, 144, and 88, respectively.

According to the latest astrolabe census, the collection of the National Museum of American History is now the fourth-largest museum collection in the world, ranking behind those of the Museum of the History of Science in Oxford, the Greenwich Maritime Museum, and the Adler Planetarium in Chicago. For that reason, it seemed particularly appropriate to subject the objects in this collection to close study. Although there have been a number of such studies of individual instruments, and good descriptive accounts of certain collections, the only publication that approached the detailed description we found desirable is Gunther's classical two-volume work published in 1932. While many of our astrolabes were included in that study, the information given was often incomplete. Gunther's unsurpassed achievement in describing the world's known astrolabes is not denigrated by the observation that we have an advantage over him in working from the object rather than the photograph, and in being able to draw on subsequent scholarship such as that of Hartner, Michel, or Kunitzsch.

We have been particularly fortunate in the fact that Sharon Gibbs was willing to undertake the arduous task of subjecting each of the astrolabes and its components to minute scrutiny and to describe her findings in meticulous detail. We are grateful to George Saliba for collaborating with her in the

translation of the Arabic inscriptions, and to David Pingree, who provided similar help with the Sanskrit. We hope that their work will encourage other subject matter specialists to provide similar descriptions. Having the results of such studies at our disposal should enable us to address the many unanswered questions concerning schools, traditions, and styles that make this subject such a fascinating field of inquiry.

Uta C. Merzbach, Curator
Division of Mathematics
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Preface

The preparation of this monograph would not have been possible without the encouragement and cooperation of Dr. Uta Merzbach, who has, for the years of my association with them, been the custodian of the National Museum's collection of planispheric astrolabes. My gratitude to Dr. Merzbach extends also to her assistants, most notably Mrs. Ona Jordan, who has presided over many of my examinations of the objects and provided quick access to photographs and prints.

This publication completes, after a long hiatus, work begun as a 1972–1973 post-doctoral research fellow at the Museum. The work was jointly sponsored by Dr. Merzbach and Silvio Bedini, then Assistant Museum Director. Mr. Bedini's interest and support have complemented Dr. Merzbach's encouragement and cooperation to lead to the publication of this volume.

Some years after I had completed my Smithsonian fellowship I learned that Dr. George Saliba, now at Columbia University, had also studied those astrolabes in the collection with Arabic inscriptions. Dr. Saliba and I agreed that collaboration would enhance our efforts. The result is this volume and the inclusion (thanks to Dr. Saliba's contributions) of Arabic transcriptions, accompanying English translations, and pertinent linguistic commentary. Dr. Saliba's research is particularly evident in the appendices on star names and gazetteers. Dr. Saliba has frequently obtained the help of Mr. H. Javadi, Mr. A. Davaran, and A. Kholdani concerning the deciphering of some Persian inscriptions. Their generous assistance is gratefully acknowledged. He is especially grateful to Professor Owen Gingerich of Harvard University, who encouraged his work on this collection.

I am grateful to Russell Cashdollar for turning my rough sketches into the professional line drawings that illustrate this publication.

Finally, I owe a special debt of gratitude to an extraordinary typist, Rosemary Regan.

Sharon Gibbs
Washington
June 1982

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Design of the Planispheric Astrolabe

Information on how to make and use a planispheric[1] astrolabe is currently available from a variety of sources.[2] A fourth-century work by Theon Alexandrinus "on the little astrolabe" apparently can be considered the prototype for all later contributions to this literature.[3] While the remarks in this section follow the tradition established by Theon, they are not intended to be a major contribution to it. They are offered primarily as an introduction to terminology employed in the catalog and the analysis of the collection of instruments which is the subject of this study.

Some basic components characterize a planispheric astrolabe no matter where or when it was made. These are the body, the suspensory apparatus, the alidade, the pin, and the star map (or rete). The functions of these parts remain fairly constant over a large geographic area and a considerable period of time. Together, the body, the suspensory apparatus, the pin, and the alidade function as an observational instrument (see Figure 10); the star map, the pin, and the body function as a model of the heavens (see Figure 13).

The body constitutes the bulk of the instrument. It is shaped like a thin disk. It has a definite front (*wajh* or *facies*)[4] and back (*ẓahr* or *dorsum*). In all but a few cases, the front incorporates a raised rim (*ḥajra* or *limbus*) and a depressed central area (*umm* or *mater*). The various surfaces of the body of an astrolabe are seldom left uninscribed. This inscription (both form and content) may be used to identify both the date (see page 13) and place of origin of any given instrument. Tables 1, 2, and 3 list the scales that may appear on the back of an astrolabe, and indicate whether each can usually be found on an instrument inscribed with Arabic characters and made in the *mashriq* (East) or the *maghrib* (West), or on a European[5] instrument inscribed with Latin characters. Figures 1, 2, and 3 illustrate the typical placement of these scales. Note that, in all cases, at least one scale serves to measure the altitude of a celestial object when the astrolabe is suspended.

Just as the scales and tables on the back of an astrolabe may be used to distinguish an Arabic from a European instrument, so too may the inscription on the front rim. Table 4 shows the

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TABLE 1.—Scales that may appear on the back of a mashriqi astrolabe (refer to Figure 1 for an explanation of location of entries in "Placement" column; refer to "Comparative Analysis" for full explanation of scales)

Title of table/scale	Placement	Units	Number of units (type)
Outer Circular	Margin		
Altitude	I, II	degrees of arc	90 (equal)
Cotangent	III, IV	feet/fingers	7–60 (unequal)
Arc	Quadrant		
Declination	UR	zodiacal divisions	6–60
Azimuth of Qibla	UR	cities	1–7
Altitude of noon sun	UR	degrees of latitude	22–50
Hours	UL, UR	1/12 of daylight	1–6
Prayers	UR	times of day	1–5
Angle	Quadrant		
Sine	UL	1° or 5° angles	18–90 (unequal)
Cosine	UL	or 1/60 of quadrant radius	60 (equal)
Box	Quadrant		
Tangent	LL(a), LR(d)	feet LL, fingers, LR	7 LL, 12 LR
Cotangent	LL(b), LR(c)	feet LL, fingers, LR	7 LL, 12 LR (equal)
Inner Circular	Quadrant		
Terms	LL and LR V, VI	zodiacal divisions	60 (unequal)
Zodiacal signs	LL and LR VII	zodiacal divisions	12 (equal)
Faces	LL and LR VIII	zodiacal divisions	36 (equal)
Lunar mansions	LL and LR IX	zodiacal divisions	28 (equal)
Inner Box	Quadrant		
Triplicities	LL and LR X	zodiacal divisions	12+ planets and natures

variety possible. Figures 4 and 5 illustrate the placement. To ensure the effective operation of the astrolabe as a model of the heavens (see below), the rim is interrupted by a hole or a projecting tooth. The *umm* or *mater* of an astrolabe, if it is engraved at all, may contain either a stereographic projection of the horizon coordinates for a given latitude (see Appendix III and Figure 6) or a list of important cities accompanied by geographic parameters (see Appendix I).

The quality of an astrolabe as an observational instrument depends on the care with which it is fitted with a means of suspension (see Figure 7). An acceptable suspensory apparatus generally consists of a rigid appendage to the disk base, called the "throne" (*kursī* or *armilla fixa*); a loop of metal, the handle (*ᶜurwa* or *armilla reflexa*), which passes through a hole pierced in the highest point of the throne and can move only in the plane of the disk base; and a metal ring (*ḥalqa* or *armilla rotunda*) with a diameter large enough to encircle a thumb and pass through the handle attached to the throne. The preceding description refers only to the basic characteristics of each element of the appratus. Above all, the combination must allow the instrument to hang plumb. Shape and the amount of decoration may vary

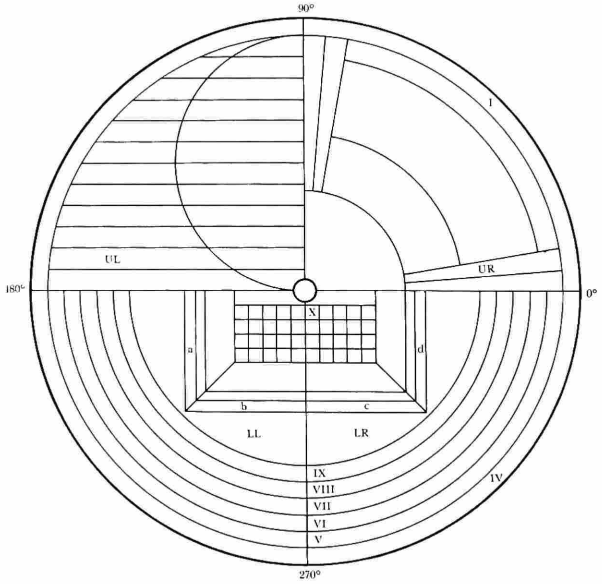


FIGURE 1.—Back of an astrolabe made in the mashriq. Numbers and letters refer to scales listed in Table 1.

TABLE 2.—Scales that may appear on the back of a maghribi astrolabe (refer to Figure 2 for the location of entries in the "Placement" column; the calendar scale may be centrally located, in which case the 365 days would divide it unequally)

Title of table/scale	Placement	Units	Number of units (type)
Outer circular	Margin		
Altitude	1,2	degrees of arc	90 (equal)
Cotangent	3,4	1/12 of gnomon	60 (unequal)
Zodiacal signs	5	zodiacal divisions	360 (equal)
Outer eccentric	Margin		
Calendar	6	days of year	365 (equal)
Arc	Quadrant		
Hours	UL	1/12 daylight	1–6
Box	Quadrant		
Tangent	LL(a), LR(d)	feet	12 (equal)
Cotangent	LL(b), LR(c)	feet	12 (equal)

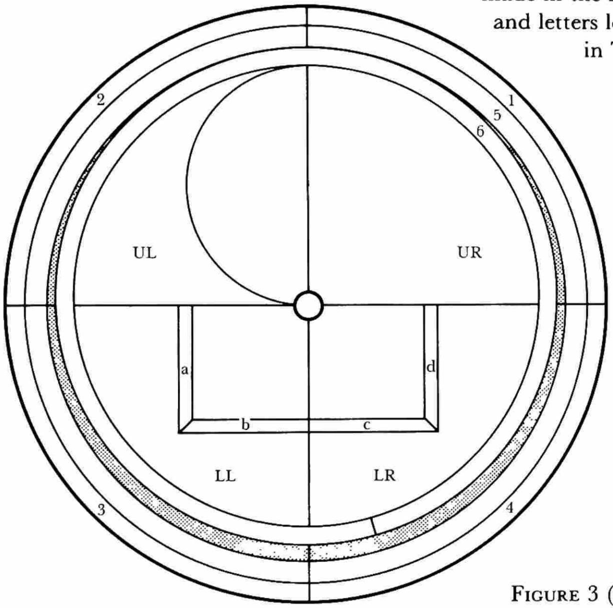


FIGURE 2 (left).—Back of an astrolabe made in the maghrib. Numbers and letters locate scales listed in Table 2.

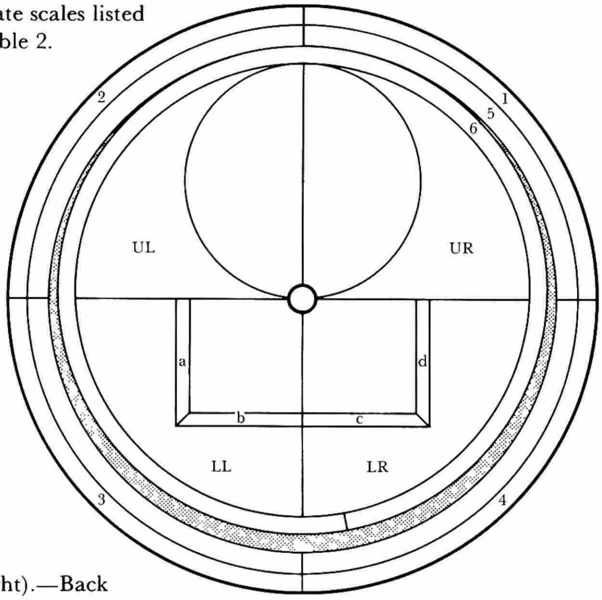


FIGURE 3 (right).—Back of an astrolabe made in Europe. Numbers and letters refer to scales listed in Table 3.

TABLE 3.—Scales that may appear on the back of a European astrolabe: summarizes the content of the back of a "standard" European astrolabe but does not characterize those instruments with universal projections (refer to Figure 3 for location of entries in "Placement" column; the calendar scale may be centrally located, in which case the 365 days would divide it unequally)

Title of table/scale	Placement	Units	Number of units (type)
Outer circular	Margin		
Altitude	1,2,3,4	degrees of arc	90 (equal)
Zodiacal signs	5	zodiacal divisions	360 (equal)
Outer eccentric	Margin		
Calendar	6	days of year	365 (equal)
Arc	Quadrant		
Hours	UL, UR	1/12 of daylight	1–12
Hours	UL, UR	1/24 of day	1–12
Box	Quadrant		
Tangent	LL(a), LR(d)	fingers or 1/60 side of box	1–12
Cotangent	LL(b), LR(c)	fingers or 1/60 side of box	1–60

TABLE 4.—Scales that may appear on the rim of an astrolabe (see Figures 4 and 5 for the placement of these scales)

Title of scale	Units	Range	Tradition
Degrees	5° and 1°	0°–360°	mashriq maghrib
Degrees	5° and 1°	4 (0°–90°)	mashriq
Winds	30°	0°–360°	European
Hours	15°	0°–360°	European

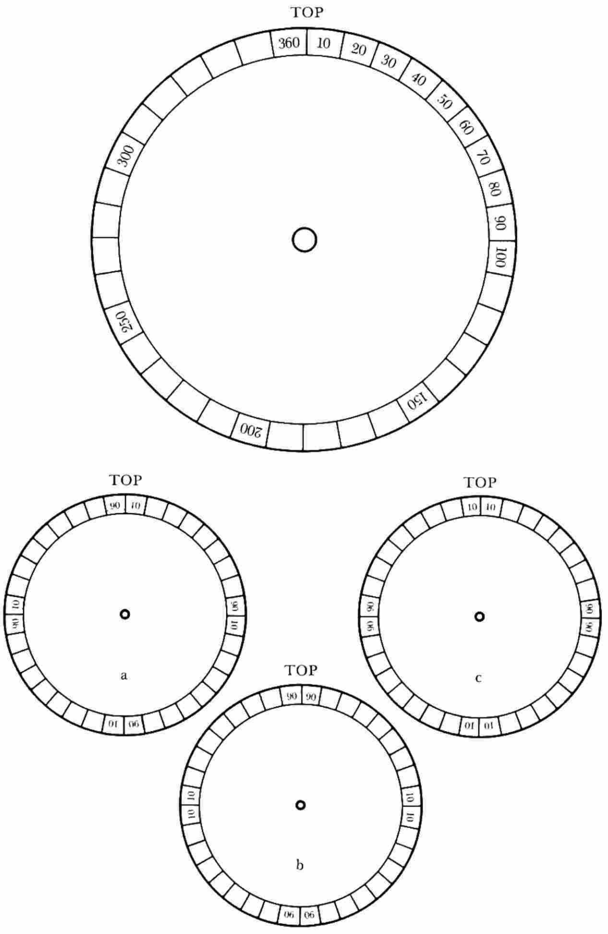


FIGURE 4.—Variations in the placement of scales on the rim of an astrolabe inscribed in Arabic characters.

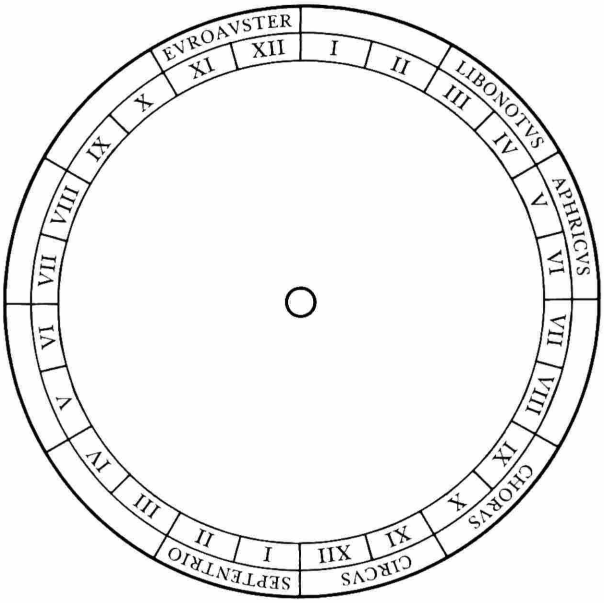


FIGURE 5.—Placement of scales on the rim of an astrolabe made in Europe.

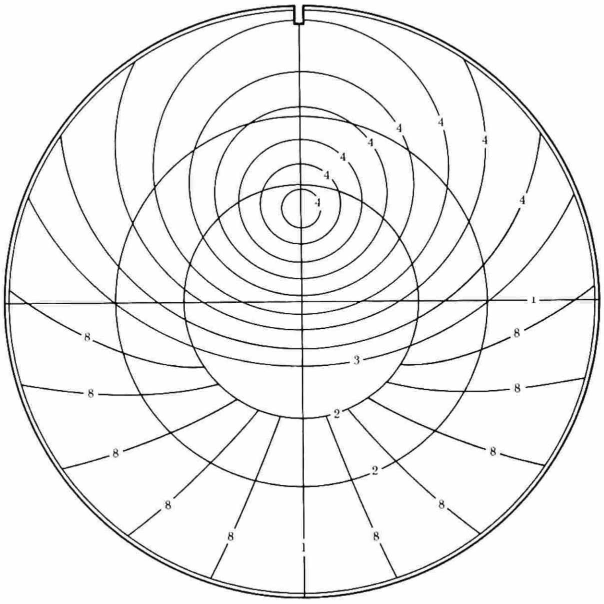


FIGURE 6.—Astrolabe plate appropriate for 36° latitude. Numbers refer to projected lines listed in Table 5.

according to the taste and ingenuity of the maker.

As is true with the suspensory apparatus, the shape of the alidade (*al-ʿiḍāda* or *regula*) may be dictated by stylistic convention. Utility demands, however, that its length be approximately equal to the diameter of the body; that it be wide enough at its center to be pierced by a small circular hole; and that each arm incorporate a beveled edge that coincides with a line (the *linea fiduciae*), which passes through the center of the

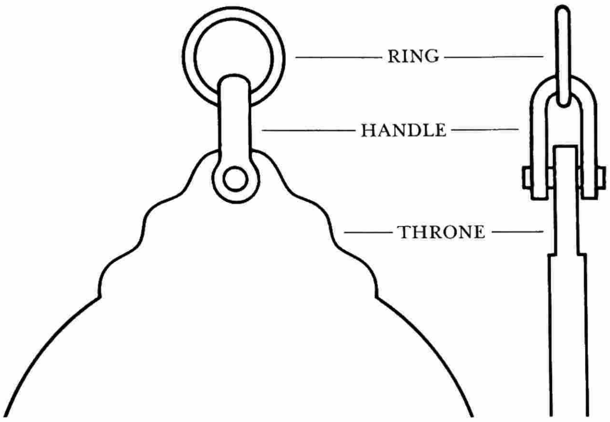


FIGURE 7.—An astrolabe's suspensory apparatus.

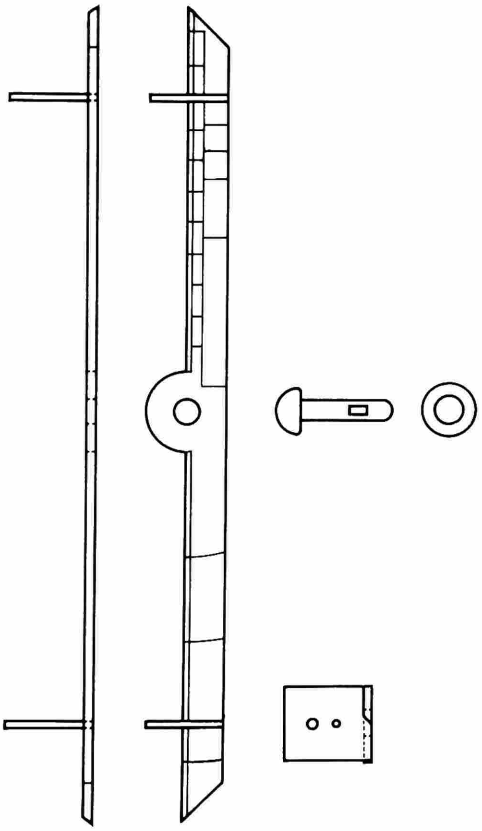


FIGURE 8.—Alidade with pin and ringlet.

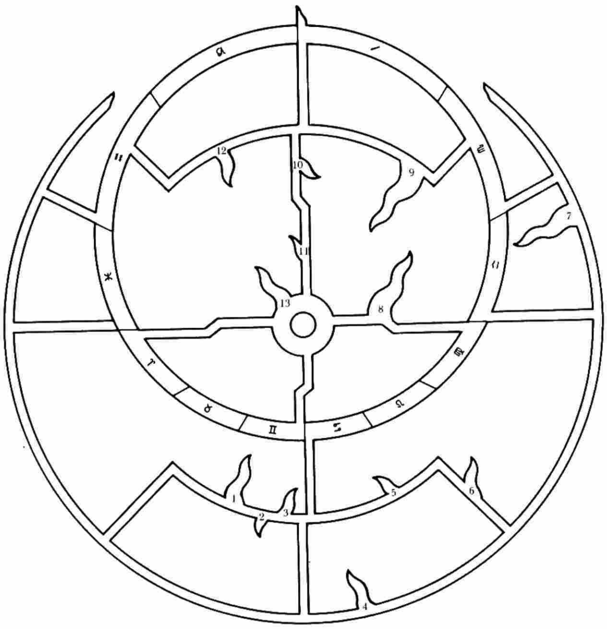


FIGURE 9.—The star map, ʿ*ankabūt*, or rete, of an astrolabe. Numbers refer to stars listed on page 56.

TABLE 5.—Coordinates that may be projected on the plate of an astrolabe (see Figure 6 for location of numbers, in parentheses here, specifying position of scales)

Projected lines	Number	Position	Tradition
Colures (1)	2	quadrant boundaries	all
Tropics and equator (2)	3	UL,UR,LL,LR	all
Horizon (3)	1-many	LL,LR	all
Altitudes (4)	15-90	UL,UR	all
Twilight	1	LL,LR	all
Azimuths	36	UL,UR,*	all
Equal hours	12-15	LL,LR	mashriq
Seasonal hours (8)	12	LL,LR	all
Houses	12	UL,UR,LL,LR	European
Prayers	4	LL,LR	maghrib

* On some astrolabes made in the Muslim world, the azimuths extend to the lower half of the plate.

small central hole. An inscription in Arabic characters and engraved lines invariably decorate the alidade of an instrument made in the mashriq (see Figure 8). No alidade is complete unless it has been fitted with two sighting plates. These are usually pierced with two holes (centered on each plate's center line). The sighting plates are affixed perpendicular to each arm of the alidade at equal distances from its center.

The complete alidade is connected to the body of the astrolabe by means of a broad-headed pin

(*quṭb* or *clavus*), which passes through the central hole in the alidade and a hole in the center of the body. The diameter of the pin is such that the alidade moves easily, but not loosely, about it as an axis. The pin is a small but crucial component of the astrolabe's design. Without it the astrolabe could not function as an observational tool. In fact, the astrolabe's other function as a model of celestial motion is equally dependent for its operation on this pin.

The openwork star map (*ᶜankabūt* or *rete*) is the basic component of the astrolabe that completes the model of celestial motion (see Figure 9). It can be viewed as a thin plate of diameter equal to the diameter of the area on the front of the astrolabe framed by the rim. It incorporates the stereographic projection of the ecliptic and of selected bright stars (see Appendices II and III). All of the metal that does not either define these projections or connect them to the center of the plate is cut away. The center itself is pierced with a small circular hole so that the star map may fit over the pin passing through the center of the body and may rotate freely about the pin as axis.

The star map is of openwork construction to allow a view of a fixed stereographic projection engraved on the surface under it. This stereographic projection of the horizon coordinates for a given latitude may appear on the *umm* or *mater*. If it does not, and occasionally even it it does, the astrolabe may be fitted with a series of solid plates (*ṣafīḥa* or *tympanum*) of diameter equal to the diameter of the openwork star map. These plates are inscribed with stereographically projected horizon coordinates for several latitudes (see Table 5 for a list of the coordinates that may appear). Each plate is modified with a notch or a tooth (see Figure 6) that fits into the corresponding tooth or notch incorporated into the rim, so that when the astrolabe is assembled, the plate is fixed inside the *umm* or *mater*.

Most European instruments and some instruments inscribed with Arabic characters include a second rotating arm, similar to the alidade, but without sighting plates. This index arm is designed to rotate freely about the pin over the star map and rim on the front of the astrolabe.

Once all the separate components of the astrolabe (front and back) are in place, a slot in the tip of the consolidating pin extends beyond the top layer just enough so that a wedge (*faras* or *equus*—literally "horse") may be fitted into it.

When used to make celestial observations, the astrolabe is suspended from its ring, and its alidade is adjusted so that either a ray of sunlight passes through the two smaller holes in the sighting plates or a star is centered in the two larger holes. The fiducial edge of the upper alidade arm registers solar or stellar altitude (Figure 10). Measurements of solar or stellar altitude can be converted with the help of astronomical tables or a knowledge of spherical trigonometry into indications of geographic position or time of day or night. Sixteenth- and seventeenth-century explorers chose to bring only the observational elements of the astrolabe to sea, and to use the resulting instrument[6] in conjunction with printed tables to help them navigate.

Those elements of an astrolabe that characterize it as planispheric replace tabulated astronomical data as interpreters of measures taken by the alidade. Whereas astronomical tables are arithmetical models of heavenly motion, the astrolabe's rete, plate, and pin constitute a geometrical model of heavenly motion. In converting stellar altitude to time of night, for example, the astrolabe's geometrical model functions as outlined below.

An engraved plate, appropriate for the observer's latitude, is fitted into the front central area of the astrolabe. The rete is positioned over the plate and the pin is replaced so that the rete may rotate around it. Assuming that one of the stars incorporated into the rete is visible above the horizon, its altitude is measured. The rete is then rotated until the representation of this star coincides with the projected circle on the plate, which represents its measured altitude. Without moving the rete, the position of that point in its

FIGURE 10.—Noah's Ark, as shown in an Indian painting of the early seventeenth century depicting the use of an astrolabe (left middle) as an observational instrument. (Freer Gallery of Art, Smithsonian Institution, Accession No. 48.8).

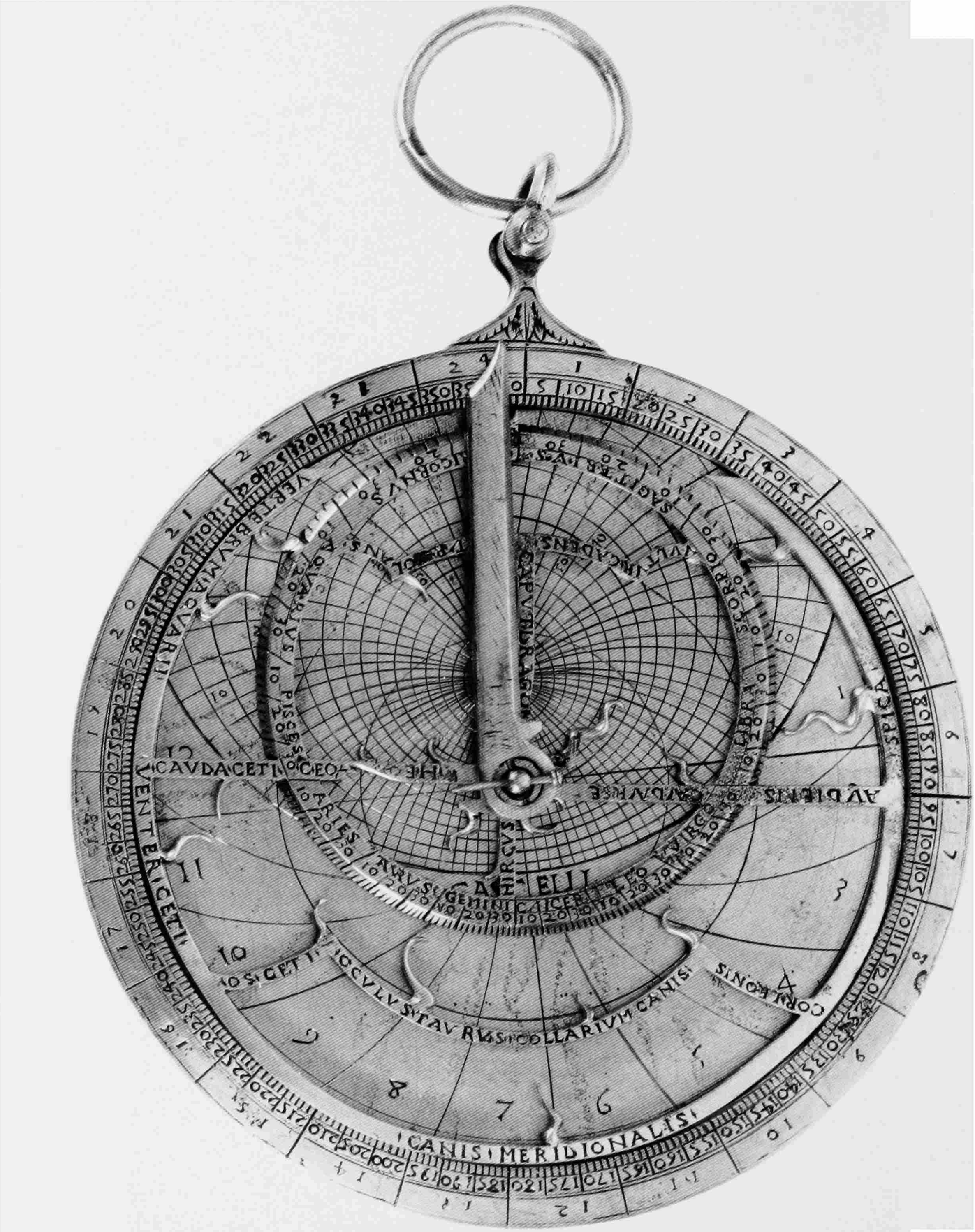


FIGURE 11.—Astrolabe No. 186. The tip of the pointer identified as *Cor Leonis* lies in the middle of the third seasonal hour.

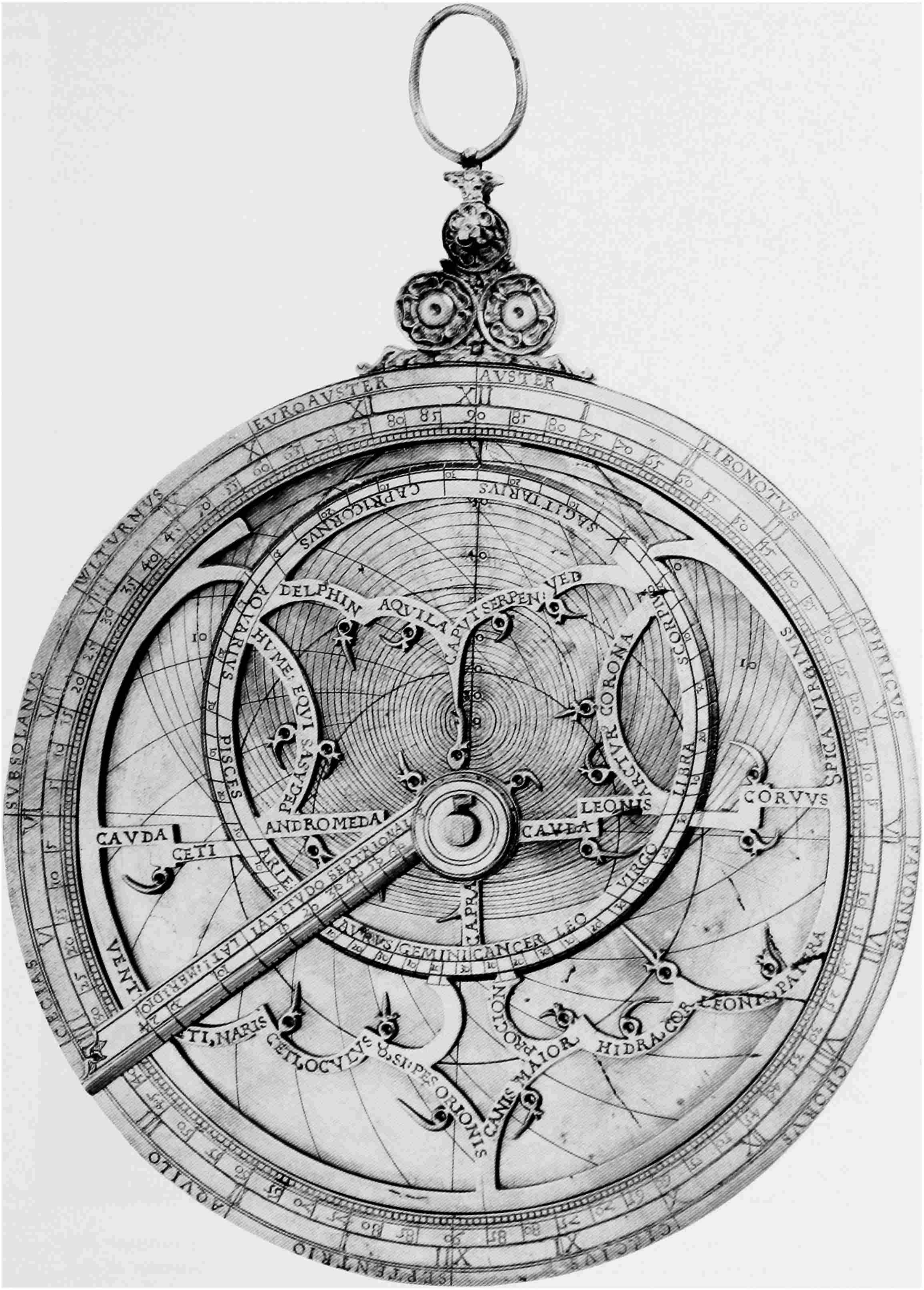


FIGURE 12.—Astrolabe No. 262. Assuming that its index arm marks the position of the sun in the ecliptic, this astrolabe marks the middle of the third equinoctial hour after midnight.

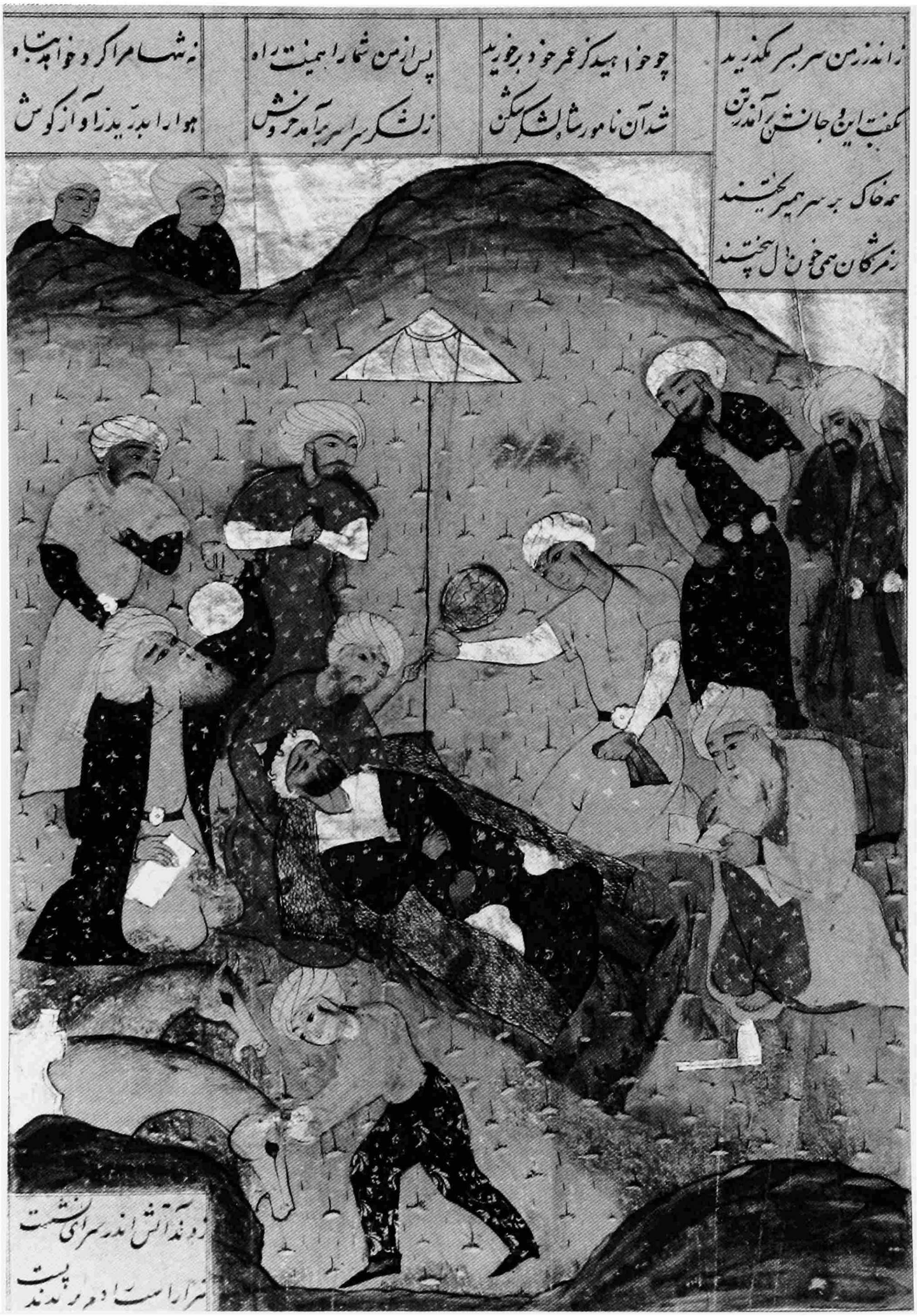


FIGURE 13.—This sixteenth century miniature depicts an astrologer using an astrolabe (left middle) to prepare the horoscope of Alexander the Great. (Metropolitan Museum of Art. Accession No. 13.228.14 44157. Ms5).

yearly path (the ecliptic) that represents the sun is noted. It coincides with a seasonal hour stereographically projected onto the plate (see Figure 11) or an equinoctial hour radially projected onto the rim (see Figure 12).[7]

The same elements of the planispheric astrolabe's design that enable it to function effectively as a timekeeper also contribute to its usefulness as an astrological computer. By adjusting the rete so that it represents the heavens at the place and moment of an individual's birth, an astrologer equipped with an astrolabe (see Figure 13) can avoid many of the complicated calculations involved in casting a horoscope. He can read directly from the adjusted instrument the ascendant, the midheaven, the descendant, and the nadir. If the plate includes projections of the boundaries of the astrological houses, he can complete the horoscope chart by reading the points of intersection between these boundaries and the ecliptic circle. In the absence of projected house boundaries he can estimate their position by using the projections of the second, fourth, sixth, eighth, and tenth seasonal hours. Figure 14 shows an astrolabe representing the heavens at noon on 9 December. The horoscopic chart indicated by this setting would incorporate the following astrologically significant points: the ascendant, Pisces 18°; the midheaven, Saggitarius 25°; the descendant, Virgo 18°; and the nadir, Gemini 25°.

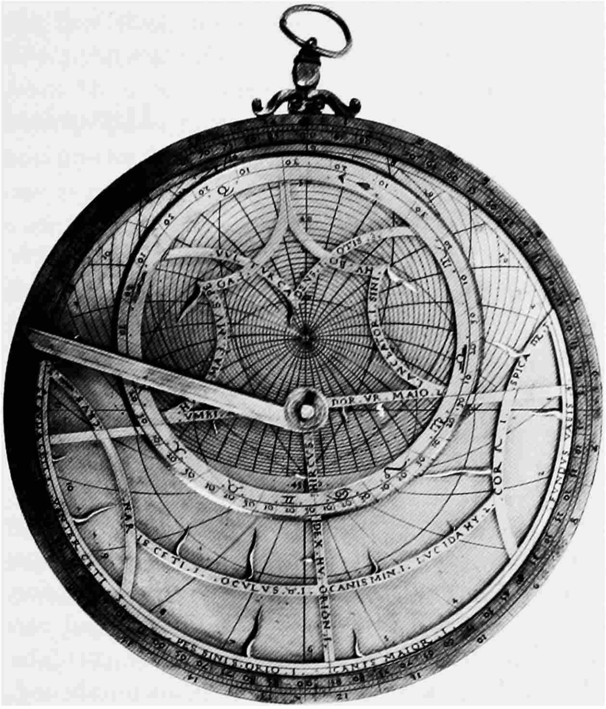


FIGURE 14.—Astrolabe No. 221. The configuration of rete and plate represent the configuration of the heavens on 9 December.

Historical Perspective

Pre-Fifteenth Century

The earliest astrolabes in the collection (made between the eleventh and fourteenth centuries) are inscribed with Kufic characters.[8] All of these examples (Nos. 4, 15, 144, 2572, 3643, and 4001)[9] are signed and dated. Their makers worked in or near Iṣfahan, Kerman, Granada, and Seville. Thus, several hundred years and several hundred miles separate these instruments from their prototype, possibly constructed for Rhodes by Hipparchus in the second century B.C. Reconstruction of the steps leading from Hipparchus's discussion of stereographic projection[10] to Muḥammad ben as-Sahli's construction of a planispheric astrolabe (No. 2572) in A.D. 1090 is not easily accomplished. There is some evidence that the theory was transmitted via a chain that included the following links: Claudius Ptolemy [A.D. 150], Theon Alexandrinus [A.D. 375], and Severus Sebokht, Bishop of Kenneserin, Syria (A.D. 660).[11]

Some time near the end of the eighth century, the Jewish astronomer Mashaʾallah discussed both the construction and use of the astrolabe in a treatise that survived to be published in Europe in a Renaissance compendium of learning.[12] Similar discussions were included in the works of a number of later Arab astronomers.[13] For example, al-Biruni completed his contribution to this latter genre in A.D. 1040,[14] just a few years before Muḥammad dated his astrolabe.

As is true of planispheric astrolabes in general, only subtle differences exist between the instrument described by al-Biruni and the pre-fifteenth-century examples in the collection. Some of these differences may reflect the needs of users; some probably the taste of makers. Among the former might be included variations in the content of the *umm* (front) and the *ẓahr* (back). The latter are apparent in the size and shape of the *kursī* (suspensory apparatus) and the pattern of the *ᶜankabūt* (star map).[15]

Users of the two early astrolabes in the collection made in Iṣfahan (No. 4) and Kerman (No. 15) apparently had need of a gazetteer inscribed in the *umm*. The practice of including such a table continued in and was confined to the eastern portion of the Muslim world[16] as long as astrolabes were made there. That users of these two early Persian astrolabes were astrologers is suggested by their apparent need for the inclusion of astrological tables in the content of the *ẓahr*. A table of lunar mansions is notably absent from both instruments, however. The omission is not surprising in light of the fact that al-Biruni's *Book of Instruction in the Elements of the Art of Astrology* does not discuss the astrological significance of this method of dividing the heavens.

Makers of these two early Persian astrolabes have most clearly asserted their individuality in the design of the *kursī*. That of Ḥamid ben Maḥmud, on an instrument dated A.H. 547 [A.D. 1152][17] (No. 4), is quite high, and pierced to form a vinelike motif. Jaᶜfar ben ᶜUmar's *kursī*, on an instrument dated A.H. 774 [A.D. 1372] (No. 15), is lower, undecorated, and pierced by only two small holes on either side of the suspensory hole. The patterns of the *ᶜankabūt*s of these astrolabes are quite similar to each other and to the illustration of an *ᶜankabūt* in at least one surviving manuscript of al-Biruni's discussion of the subject.[18] The only difference lies in Jaᶜfar ben ᶜUmar's attempt to introduce decorative curves into the basic functional design. The two symmetric "dips" in the equatorial band are characteristic of Jaᶜfar's work.[19]

Of the four early astrolabes in the collection inscribed with maghribi script, two (Nos. 144 and 4001) were certainly made in Moslem Spain. The plates of a third (No. 2572) also suggest a Moorish origin. The same may be said for the fourth example (No. 3643), engraved with a now obliterated signature and date. The *umm* of each of these instruments contains the stereographic pro-

jection of horizon coordinates for a specific latitude (i.e., the network usually found on a plate). The latitudes are: 37°30′, 66°, 90°, and 90°.

All four of these Moorish astrolabes illustrate the fact that such instruments, inscribed with Kufic letters and made in the western portion of the Moslem world, carry no astrological tables. Instead each is engraved with scales (zodiacal calenders) that correlate solar position during the year with a date in the Christian calendar.[20] Instructions for dividing these scales are given in surviving editions of Masha᾿allah's treatise but not in al-Biruni's.

The variety apparent in the *kursīs* and ᶜ*ankabūts* of Persian instruments is also apparent in the analogous elements of these Moorish astrolabes. Simple *kursīs* combine with relatively elaborate ᶜ*ankabūts*. Aḥmad ben Ḥusain's ᶜ*ankabūt*, on an instrument dated A.H. 704 [A.D. 1304] (No. 144), is remarkable in that, while it differs noticeably from other early examples, it contains elements that reappear in the ᶜ*ankabūts* of later instruments (see, for example, No. 2568, dated A.H. 1103 [A.D. 1691] and No. 2571 dated A.H. 910 [A.D. 1504]).[21] The basic design of Muḥammad ben as-Sahli's ᶜ*ankabūt* is similar to that of the early Persian examples in the collection. The ᶜ*ankabūt* of Muḥammad ben Fattuḥ, on an instrument dated A.H. 621 [A.D. 1224] (No. 4001), does not survive.

Fifteenth Century

Remaining evidence suggests that manuscripts on the construction and use of the astrolabe were available in Europe at least as early as A.D. 1054.[22] Chaucer undoubtedly relied on one of these when he composed in A.D. 1387 the first English treatise on the subject, "Brede and Milke for Childeren."[23] Published works in Latin appeared in various European centers of learning throughout the sixteenth century.[24] These representatives of the "construction and use" genre usually differed only in the epoch[25] of the table of fixed stars recommended for inclusion in a rete. The identification of instruments that are engraved with Latin characters and are contemporary with this early Latin literature has been complicated by the fact that, until the sixteenth century, few European astrolabe-makers bothered to date their work. Dates for instruments from this period have been assigned, however, based on epigraphic clues and on the calendric correlate of the vernal equinox as revealed by scales engraved on the back of each instrument (see note 20).

The two very early European instruments in the collection have been dated by means of their zodiacal calendars.[26] No obvious signature appears on either astrolabe, although the earlier of the two (No. 304) carries a curious configuration of letters stippled on the upper right and left quadrants of its back (see Figure 15).

The zodiacal calender and the rete of the astrolabe with the stippled lettering (No. 304) indicate that it was made to be used in the mid-fifteenth century. It was designed to be used at a single latitude (52°), a characteristic it shares with some other European instruments.[27] The second probable fifteenth-century European astrolabe in the collection (No. 186) includes six plates, about as many as one would expect to find in con-

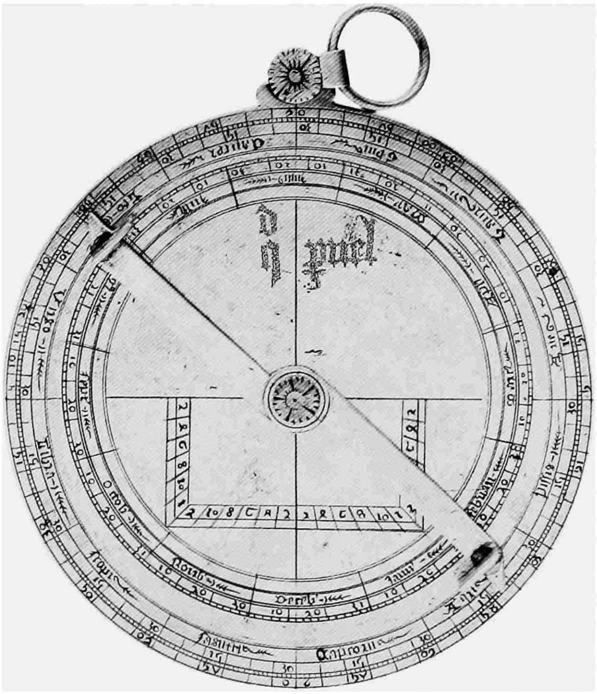


Figure 15.—Astrolabe No. 304. The stippled letters may be a maker's signature, or, more probably, an owner's mark.

temporary examples from Persia or North Africa.

Differences between European astrolabes and astrolabes made in the *maghrib* are even more subtle than differences between the latter and astrolabes originating in the *mashriq*.[28] Astrolabes used in Moorish Spain can hardly be distinguished from those used in Lancastrian England or Medician Italy. However, the evidence on preserved instruments does suggest that Europeans had no need for the circular cotangent scales found on most maghribi instruments. Certainly this scale is not found on any of the European instruments in the collection.[29]

A second subtle difference between European and Moorish tradition can be seen in the inclusion of a scale of equal hours on the rim of an instrument made in Europe. As a rule, no analogous scale appears on a Moorish instrument.[30] A similar distinction between European and Moorish preferences for timekeeping scales can be made with respect to the scale of seasonal (or unequal) hours engraved on the back of astrolabes from each area. The scale is likely to fill both upper quadrants of the back only on European instruments.

Astrolabes in the collection show that European makers are as likely to distinguish themselves through the design of the rete as Persian or Moorish makers are through the design of the *ᶜankabūt*. The unsigned member of the pair of early European astrolabes in the collection (No. 304) has been assigned to an English source based primarily on the recognition of similarities between the rete pattern of this instrument and the rete pattern chosen by Chaucer to illustrate his "Brede and Milke."[31] Although it is clear that the maker borrowed something from this pattern type, he has clearly modified it to suit his taste. The early Italian instrument in the collection (No. 186)[32] incorporates a rete with a functional

FIGURE 16.—Astrolabe No. 2006. Lines for a sundial and the probable dial maker's signature can be seen on the back of the rete (at left).

FIGURE 17.—The rete of Chaucer's astrolabe, as illustrated in his treatise, "Brede and Milke for Childeren."

design that was adopted by makers of various European nationalities.[33] It is distinctively simple, much like the early Persian *ʿankabūt*, but with the addition of an upper equinoctial arc.

It is possible that a third astrolabe in the collection (No. 2006) may be added to the group of fifteenth-century instruments. Although it is unsigned, its inscriptions contain a number of clues to its origin. Some of the clues are misleading. The majority of the inscriptions, including the zodiacal calendar, suggest a fifteenth-century origin. The diversionary clues, all inscribed on the back of the rete, include a maker's name (see Figure 16); they appear to derive from the seventeenth century.[34] The rete's resemblance to one used to illustrate an edition of Chaucer's work on the astrolabe (Figure 17) is noteworthy.

SIXTEENTH CENTURY

All but one of the sixteenth-century astrolabes in the collection are the work of European makers. This distribution reflects the distribution of Persian and Moorish makers vs. European makers in the whole corpus of extant sixteenth-century astrolabes. There exists an overwhelming majority of European examples.[35] The one sixteenth-century astrolabe in the collection inscribed with

Kufic characters of maghribi origin (No. 2571) is dated A.H. 910 [A.D. 1504]. Except for the addition of lines marking the times of Muslim prayer on each of its plates, there is little to suggest that use of this instrument differed from use of contemporary European examples. The pattern of the ᶜ*ankabūt* is distinctive, identifying a maker (ᶜAli ben Muḥammad ben Abdallah ben Faraj) influenced by Moorish decorative style (circular support of the equinoctial arc, Moorish arches at the ends of the equinoctial arc, studded balls as bases for star pointers).

European fascination with the astrolabe in the sixteenth century is suggested not only by the number of instruments that survive, but also by the number of published works on the topic that appeared during the century. A list of some of the most popular publications (i.e., works that appeared in several editions) would include works by: Gregor Reisch (quoting Mashaʾallah) (Friburg, 1503), Johannes Stöffler (Oppenheym, 1512), Reiner Gemma Frisius (Antwerp, 1556), Egnazio Danti (Florence, 1569), John Blagrave (London, 1585), and Robert Tanner (London, 1587). The publications are evidence of an international European interest. Instruments in the collection support this evidence.

Four sixteenth-century European instruments in the collection are signed and dated as follows: Georg Hartman, 1537 (No. 262); M.P., 1542 (No. 221); I Galois, 1548 (No. 204); Philip Danfrie, 1584 (No. 2007). The one anonymous sixteenth-century instrument (No. 2005) is quite similar to the astrolabe by Egnazio Danti illustrated in Gunther.[36]

If the instruments in the collection are any indication, it would seem that European makers were far more likely to introduce variety into the contents of the back of an astrolabe[37] than were their Persian or Moorish counterparts. One astrolabe includes a quadrant (No. 2006). One includes a De Roias projection (No. 2005). One has a table of stars, along with the longitude, declination, and magnitude of each star (No. 204). One has a set of perpetual calendar wheels (No. 2007). One has a scale of unequal hours (No. 262). One includes both a scale of unequal hours and a scale of equal hours (No. 221). Only two scales seem to have universal appeal: a scale correlating the Christian calendar with solar position (zodiacal calendar), and the ubiquitous shadow square.

Examples in the collection suggest that, in addition to zodiacal calendar and shadow square, at least one other common element characterizes sixteenth-century European astrolabes. The divisions of the astrological houses have been included on each plate. These divisions appear on the plates of only one Persian instrument in the collection (No. 65, attributed to an eighteenth-century maker). Both Mashaʾallah and al-Biruni advocate using the unequal hour lines as house divisions. On the whole, the Persian astrolabes document the popularity of this practice.[38] It is just possible that European inclusion of house lines distinct from unequal hour lines in the sixteenth century is evidence of the impact of Regiomontanus's contribution to astrology.[39] The inscribed houses consistently conform to the method of division suggested by Regiomontanus as an alternative to methods attributed to Alcabitus or Campanus.[40]

The youngest European instrument in the collection (No. 2007) includes evidence that European makers distinguished themselves not only by means of a preferred rete design but also by their choice of materials. Philip Danfrie's astrolabe with its elaborate baroque rete is made of heavy paper that has been glued to a wooden form and is fitted with a brass alidade.

With over 20 of his astrolabes surviving to the present, Georg Hartman[41] appears to be the most productive of European astrolabe makers. The example of Hartman's work included in the collection (No. 262) documents his obviously successful method of production. The telling evidence appears in the form of a very small number "12" engraved in unobtrusive places on each of the separable parts: in the depression on the front of the body, at the lowest point of each plate, on the back of the rete, the alidade, and the index arm. Hartman's use of such a numbering system suggests that he managed a workshop in which several astrolabes were being finished simultane-

ously. There would be no need to number the component parts of astrolabes completed one at a time.

Seventeenth Century

Those astrolabes in the collection that date from the seventeenth century are all inscribed with Arabic characters.[42] These astrolabes are typical of the larger corpus of seventeenth-century astrolabes by Moorish or Persian makers in that they exhibit stylistic variations associated with three distinct manufacturing locales, and they are products of families of instrument makers.

Henri Michel has, with typical perspecuity, discussed time- and space-dependent elements of astrolabe design in Chapter 20 of his *Traité*.[43] These elements comprise a few basic "styles" subject to elaboration by individual makers. Of the styles identified by Michel, three are associated with instruments inscribed in Arabic characters: the Hispano-Moorish, the Persian, and the Indo-Persian. The collection includes seventeenth-century examples of all three styles.

The Hispano-Moorish example, made by Ḥasan ben Aḥmad al-Baṭṭuṭi (No. 2568), is dated A.H. 1103 [A.D. 1691]. Characteristic elements of its design include a simple throne, undecorated except for a single engraved marginal line, and a rete fitted with four turning knobs, incorporating star pointers shaped like thin flames attached to pierced trefoils and mounted on rectangular bases.

Two instruments in the collection (Nos. 44 and 25) made in the Persian style are associated with the name Muḥammad Mahdi (al-Yazdi),[44] who is known to have been involved in the production of some 20 other astrolabes during the period between A.D. 1640 and 1670. According to the signature, Mahdi "decorated" one of these instruments (No. 25) in A.H. 1078 [A.D. 1667]; he signed the other (No. 44) without dating it and without designating his contribution.[45] The recognizably Persian aspects of Mahdi's astrolabes include a throne shaped like a scalloped equilateral triangle and decorated with embossed vines, flowers, and inscription on a stippled background. Like other Persian retes, Mahdi's are foliated; star pointers are leaf-shaped. Following Persian tradition, he has placed his signature in a cartouche below the shadow squares on the back of the astrolabe.

In an attempt to characterize the Indo-Persian style, Michel has remarked that it is to the Persian style "as German rococo is to regency: too much ostentation; too many flourishes; an awkward and artificial grace."[46] In the collection, the works of Muḥammad Muqim (No. 86) and Ḍiya ʾal-Din Muḥammad (No. 87), both of Lahore,[47] serve as specific examples. Their Indo-Persian origin is evident in pierced thrones[48] and in the extensive use of dashed division lines.[49] Neither of these two specific examples includes a functioning rete. Other instruments by these same makers are equipped with quite delicate retes. If the retes of the two signed Indo-Persian astrolabes in the collection were like these, it is easy to see why they did not survive.

Indo-Persian elements can be recognized in each of the remaining four seventeenth-century astrolabes in the collection, although there is no explicit evidence that any originated in Lahore. All have pierced thrones. One (No. 2569) also includes extensive use of dashed lines and a well-preserved delicate rete. It is unsigned. One (No. 85) is signed by a maker from Qayen (in Eastern Persia).[50] The fact that its rete is missing suggests that it may have been delicate. Certainly the maker's extensive use of dashed division lines may be interpreted as Indo-Persian influence. Although Gunther described as "Indian" the A.D. 1611 work of ᶜAli ben ᶜAwaḍ (No. 70), there is no evidence other than the pierced throne that it really is. The stylistic origins of the instrument signed by Khalil and dated A.H. 1067 [A.D. 1656] (No. 2567) are equally uncertain.

At all times in its history, the skills necessary for designing the astrolabe, in Hispano-Moorish, Persian, or Indo-Persian style, very often were cultivated by more than one member of an instrument-making family. The classic example in the Muslim world is the family of al-Hadad of Lahore.[51] Astrolabes signed by al-Hadad and then by his son ᶜIsa remain from the sixteenth and early seventeenth centuries.[52] Muḥammad

Muqim, who in A.H. 1053 [A.D. 1643] signed an astrolabe (No. 86), was al-Hadad's grandson. He had a brother, Qa᾿im Muḥammad,[53] whose son Ḍiya᾿ al-Din Muḥammad, a great-grandson of al-Hadad, made in A.H. 1070 [A.D. 1659] an astrolabe (No. 87) now also in the collection. This remarkably well-established family interest in instrument making apparently died with Ḍiya᾿ al-Din. At least, no known subsequent makers claim a lineage through Ḍiya᾿.

In the inscription on his instruments the prolific Persian astrolabe maker Muḥammad Mahdi identified himself as the son of Muḥammad Amin. This Amin may be the maker of two seventeenth century astrolabes bearing that signature, or he may be Muḥammad Amin ben Mirza Khan who signed an astrolabe in A.H. 996 [A.D. 1587].[54] Ḥasan ben Aḥmad's membership in a North African instrument-making family can be firmly established. His (probably younger) brother Muḥammad ben Aḥmad al-Baṭṭuṭi[55] made both quadrants and astrolabes in the early eighteenth century.

Eighteenth Century

By the eighteenth century, the astrolabe had all but disappeared from the workshops of European instrument makers.[56] However, astrolabes inscribed with Arabic characters surviving from the period are no less numerous than those surviving from preceding centuries. Thirteen eighteenth-century astrolabes can be identified in the collection (almost 25 percent). Many of these originated in Iṣfahan, marking that Persian city as a manufacturing center of the importance of Lahore or Yazd. Iṣfahan's most prominent astrolabe maker and decorator was ᶜAbd al-A᾿imma. His name appears on roughly 50 instruments. A careful comparison of many of these recently undertaken by Gingerich, King, and Saliba, revealed several to be deliberate forgeries. These forgeries contribute as much to the affirmation of ᶜAbd al-A᾿imma's reputation as do the authentic instruments which carry his signature. It is not easy to determine when the forgeries were made; but their existence does suggest that, at some point in its history, the value of a Persian astrolabe could derive more from the reputation of its supposed maker than from the precision of its component parts.

All four of the astrolabes signed by ᶜAbd al-A᾿imma in the collection (Nos. 31, 37, 39, 40) appear to be authentic examples of his work. Characteristically,[57] none of the four astrolabes is dated. On three (Nos. 37, 39, 40) ᶜAbd al-A᾿imma's signature appears alone. On one (No. 31) he is identified as the decorator of an instrument made by Muḥammad Amin ben Muḥammad Ṭahir.[58] By comparing these four astrolabes it is possible to distinguish ᶜAbd al-A᾿imma's role as "maker" from his role as "decorator." As maker he apparently fashioned each of the component parts of the astrolabe: he pierced the sighting plates of the alidade with two holes; he cut the rete in a distinctive style; he habitually paired certain projections when he engraved the plates; and he selected the tables to be included on the back of the instruments. Equivalent component parts show the hand of Muḥammad Amin in the instrument "made" by him. It would seem that when ᶜAbd al-A᾿imma functioned as decorator, he worked with partially engraved parts supplied to him by a maker. He was responsible only for the engraved details.

The remaining eighteenth-century astrolabes in the collection (those not signed by ᶜAbd al-A᾿imma) fall into three categories: well-made Persian instruments; a well-made Indo-Persian instrument; and poorly made instruments of uncertain origin.

Two of the fine Persian astrolabes (Nos. 42 and 65) exhibit clear affinities with and yet are not identical to the work of ᶜAbd al-A᾿imma and his collaborators. One (No. 42) was made by Ḥajji ᶜAli;[59] the other is unsigned. At least two, and perhaps a third astrolabe in the collection, serve as evidence that ᶜAbd al-A᾿imma's style did not entirely dominate the eighteenth century. ᶜAbd al-Ghafur (ben Muḥammad Sa᾿id) made one of these (No. 55) in A.H. 1198 [A.D. 1783], and is almost certainly the maker of a second (No. 54), dated A.H. 1196 [A.D. 1781], but unfinished and unsigned. The two instruments exhibit similarities in the pattern of their retes, the selection of

scales on the back of each instrument, and the inscription of the scale on the rim. This latter inscription identifies the rim scale as four 90° arcs, a practice associated with seventeenth century Indo-Persian instrument makers.[60] Yet another unidentified Persian maker whose undated work is included in the collection (No. 47) inscribed the rim scale in this manner. This anonymous maker also resembles ʿAbd al-Ghafur in the shaping of the throne (exhibiting Indo-Persian tendencies) and in the dividing of the upper left quadrant of the back; he otherwise exhibits a unique style.

A single undated astrolabe (No. 88) of definite Indo-Persian origin appears, judging on the basis of the placement of stars in its rete,[61] to belong to the group of eighteenth-century astrolabes in the collection. No maker's name is engraved on the instrument, but a probable owner (Ṣahibuhu Maghfur al-Ḥusayni al-Jilani) identified his property along the outer edge near the throne. The relative uncertainty of its date of origin does not diminish the value of this astrolabe in defining the enduring aspects of the Indo-Persian style. These include the high pierced throne and elaborate delicate rete familiar from seventeenth-century examples. They also include a tendency on the part of the maker to used dashed lines in his engraving.[62] Further confirmation of its Indo-Persian origin is provided by the two prayer lines graphed in the upper right quadrant of the astrolabe's back. A comparison of ʿAbd al-Ghafur's works with this example emphasizes the former's Indo-Persian tendencies.

An astrolabe signed by Muḥammad Ṣadiq (No. 52), dated A.H. 1189 [A.D. 1775], and two anonymous instruments (Nos. 57 and 66), also believed to be eighteenth century, together document the existence of a class of technically correct but aesthetically unremarkable products of the astrolabist's workshop. The number and placement of divisions on these instruments suggest that their makers understood the astrolabe's function but were not inclined toward precision or elaborate decorative detail. Two of these astrolabes (Nos. 57 and 66) have a single feature in common with Indo-Persian instruments; that is, the normal positions of "feet" and "finger" divisions of tangent and cotangent scales (feet-left, fingers-right) have been reversed (fingers-left, feet-right). These instruments, though not of fine quality, should in no way be confused with fake or pseudo-astrolabes. Examples of this latter type in the collection are discussed later (see p. 20).

Nineteenth Century

By no means confined to the late eighteenth century, astrolabes of marginal quality more often than not date from the nineteenth century. One candidate for this category, dated A.H. 1216 [1801], bears the signature of Ṣadiq (No. 53). It so closely resembles the work of Muḥammad Ṣadiq described above that the former is surely a copy of the latter, executed by Ṣadiq or perhaps by ʿAbd al-Karim.[63] The two instruments may be distinguished on the basis of the units comprising each rim scale. On Muḥammad Ṣadiq's astrolabe this scale is divided into 5° intervals; on Ṣadiq's astrolabe, this scale is divided into 6° intervals.

A pair of nineteenth-century instruments in the collection serves to illustrate how a well-made, if simple, astrolabe can serve as a model for a less exacting maker. Unfortunately, nothing is known about the place and time of origin of the finer member of this pair (No. 3811). Its gazetteer is distinctive in that the reported longitudes have apparently been measured from the observatory at Greenwich rather than from the Fortunate Isles.[64] This same distinctive gazetteer fills the *umm* of the astrolabe signed by Mirza Jahan Bakhsh (No. 63), also in the collection. This and other similarities between the two instruments suggest that the latter is a fairly faithful "copy" of the former. There is no indication that these two astrolabes are the products of one maker. Bakhsh's workmanship has an uneven quality not apparent in the anonymous effort. By inscribing his 5° rim scale so that it begins one division to the left of the meridian, Bakhsh has revealed the limits of his understanding of both the construction and the use of the astrolabe.

The collection contains two astrolabes dated A.H. 1281 [1864]. One of these (No. 61) has been

signed by Ṣaḥib ᶜAli Kabir Khan; the other (No. 62) carries the signature of ᶜAlaᵓ al-Din. The two instruments are remarkably similar in all respects except quality of workmanship. ᶜAlaᵓ al-Din's astrolabe may be a copy of, but is by no means equivalent to, the well-made astrolabe signed by Kabir Khan. Kabir Khan's instrument is itself at least reminiscent of the eighteenth-century astrolabes signed by ᶜAbd al-Aᵓimma. The influence is most apparent in his choice of rete pattern, but it extends to decorative details on the back and plates.

Yet another pair of astrolabes can, on the basis of quality of workmanship and placement of stars, be traced to a nineteenth-century origin. The instruments are virtually identical from rete, through plates, to back. Neither one carries a maker's name. Because it is complete and carefully (if not finely) made, one instrument (No. 2566) appears to be the model member of the pair. The unfinished, carelessly worked state of the other (No. 64) identifies it as the "copy." The gazetteer of each instrument begins with Iṣfahan, suggesting that this may have been the site of manufacture. A comparison between these twins and the works of ᶜAbd al-Aᵓimma and his Iṣfahan school reveals a definite difference in attention to detail and perhaps supplies subtle commentary on changes in the Muslim world.

Like Kabir Khan's astrolabe, an example in the collection signed Ḥamza (No. 59) includes a rete patterned after those included on instruments signed by ᶜAbd al-Aᵓimma. Ḥamza's astrolabe is dated A.H. 1268 [A.D. 1851]. His workmanship is creditable. An anonymous and undated astrolabe in the collection (No. 49) also incorporates one of ᶜAbd al-Aᵓimma's rete designs. The relatively inferior workmanship on this example suggests that it probably should be attributed to a nineteenth-century maker. None of the other nineteenth-century instruments in the collection exhibit the independent quality of workmanship evident in the effort of Muḥammad Akbar, dated A.H. 1234 [A.D. 1818] (No. 58).[65] His inscriptions are clear; his graphs and scales accurate; his decorative details beautifully executed. There is no evidence that he borrowed his rete pattern from an earlier maker. Muḥammad Akbar's work identifies him as one of the last of the true "Asṭurlabi," exhibiting the qualities of both scientist and artisan.

One last nineteenth-century instrument in the collection remains to be described (No. 4000). Except for a brief Persian inscription on the *kursī*, it is inscribed in Sanskrit characters.[66] A Sanskrit inscription in the *umm* identifies the maker of this astrolabe as Vitrabhadra, the son of Rama; the date is 1805. The Persian inscription identifies an owner, Rama of Jodhpur, who acquired the instrument in 1815. The accuracy of the division and inscription of the scales of this astrolabe indicate that the maker was a knowledgeable astrolabist. Some of these scales are familiar, some distinctive. The shadow squares are examples of the former. On Indo-Persian instruments made in Lahore, the left square is divided into fingers; the right into feet. Curiously, the placement is reversed on this Sanskrit example just as it is on Persian astrolabes. A distinctive scale relating solar declination to degrees of right ascension occupies the lower half of the back of the Sanskrit astrolabe. No other instrument in the collection carries such a scale.

Pseudo-Astrolabes

There exists no more convincing evidence of the diminished scientific role of the nineteenth-century astrolabist than the number of astrolabe-like instruments characterized by incoherent if not entirely nonsensical inscription. The National Museum of American History preserves four examples of these pseudo-astrolabes (Nos. 2570, 4002, 4003, 4004). Objects like them may be purchased any day in the markets of the Middle East. They are in no way to be confused with functional astrolabes. It is, however, easy to see how they could be.

Pseudo-astrolabes have all of the separate pieces of their functional counterparts: body, plates, rete, alidade. However, any resemblance between the two classes of objects ends here. The body of a pseudo-astrolabe is characterized by a lack of plate holder (no tooth, notch, or cylinder

in the *umm*). Each plate, in turn, lacks the means to be held (no notch, tooth, or hole). The rete is characterized by a symmetry, which also extends to the placement of the star names. There are invariably no sighting holes in the "sighting plates" of the pseudo-alidade.

Inscription on a pseudo-astrolabe is, at the most, neat. Engraved lines may be carefully, if incorrectly, placed. "Pseudo" does not necessarily mean sloppy. Respectable appearances can be deceiving. A neatly engraved rim scale with divisions marked in order "80 5 85 5 70 5 75" (as on No. 2570) is no rim scale at all. Ten neatly engraved lines do not constitute a projection of seasonal hours. Pseudo-plates that carry projections forming geometric designs have only that to recommend them. They have no astronomical significance, and are of no use to serious astrologers. In their clumsy, superfluous way, pseudo-astrolabes serve to illuminate the valued qualities of a scientific instrument: accuracy, precision, and utility.

Comparative Analysis

This comparative analysis of the collection focuses on each of the functional elements of the instruments: suspensory apparatus, throne, rim, front central area, back, plates, rete, alidade, and index. Whenever a scale is discussed, both its position and its division units are reported before any general remarks are made. Conventional trigonometric coordinates are used to specify the positions of scales or other features on the astrolabes. Thus, a scale that extends "from the 0° point counterclockwise around the rim to the 90° point" falls in the quadrant illustrated in Figure 18. A "tooth at 90°" specifies the feature shown in Figure 19. Discussions of the use of parts of the astrolabe generally rely upon statements made by Mashaʾallah, al-Biruni, or Chaucer.

Size

Astrolabes in the collection range in size from 75 mm in diameter (No. 15) to 248 mm in diameter (No. 2005). This is fairly representative of extant portable astrolabes, except for the very large instruments (284–590 mm) made in Europe in the sixteenth century by the Arsenius brothers. Few of the makers represented in the collection can be said to prefer a particular size. Neither is it possible to identify a given period of time in which astrolabes of uniform dimension were constructed.

Suspensory Apparatus

Astrolabes in the collection fully illustrate the variety one is likely to encounter in the means by which this instrument is suspended. In general the apparatus consists of a stirrup-shaped handle with an axle passing through the throne from front to back (see Figure 7) and an attached ring which, as Chaucer points out, can be "put on the thumb of thy right hand when taking the height of things."[67] On most instruments inscribed in Arabic characters the ring passes through an opening in the handle. Mashaʾallah emphasizes the importance of beveling the edges of the contiguous parts "lest their movement be impeded." Several instruments show that makers paid attention to this detail: good examples in the collection are Nos. 37, 57, 85, 144, 2569. For the most part, the handles of instruments inscribed in Arabic characters are quite plain, but on some examples (e.g., Nos. 54, 55, 64, and 87) it has the shape of a Moorish arch. On some European instruments (e.g., Nos. 221, 2006, 2007) the top of the handle has been pierced and fitted with a rotating pin to which the ring is attached (see Figure 20).

Throne

The Mashriq

Thrones on those astrolabes in the collection originating in the mashriq seem to fall naturally into three categories: high and pierced, high and inscribed, of medium height and simple decor. The high, pierced variety tends to be associated with Indo-Persian makers, the Lahore school of the seventeenth century. These include especially Nos. 70, 85, 86 (in this example, plates cover the original pierced throne), 87, 88, 2567, and 2569. At least one high, pierced example (No. 4) was made in Iṣfahan in the twelfth century, suggesting an early source for the Indo-Persian style.

Astrolabes in the collection suggest that at least as early as the seventeenth century, Persian makers considered the throne to be an appropriate location for inscriptions. The most popular is a brief quotation from the Koran which incorporates the word *kursī*. It appears on Nos. 39, 55, and 66, all made in the eighteenth and nineteenth centuries. Placement of this passage on the *kursī* of an astrolabe amounts to a religious dedication. Occasionally, when it is not the appropriate passage from the Koran, the throne inscription will identify either the person who commissioned the astrolabe (No. 40), or the maker of the instrument (No. 63). On at least one example (No. 59) the

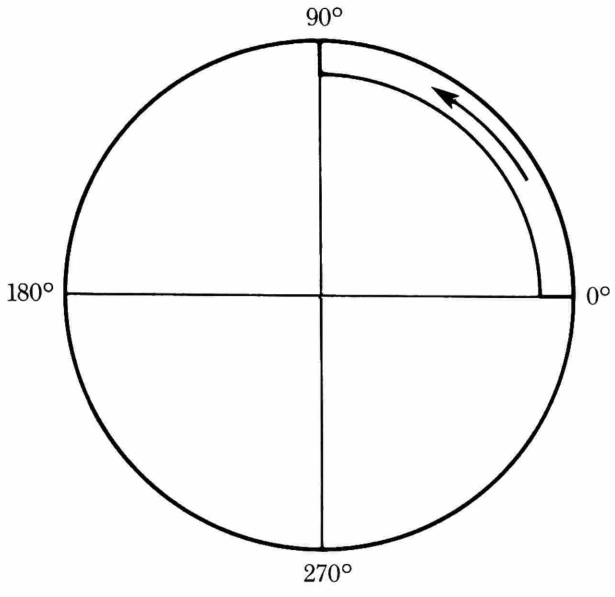


FIGURE 18.—Scale extending from the 0° point counterclockwise around the rim to the 90° point.

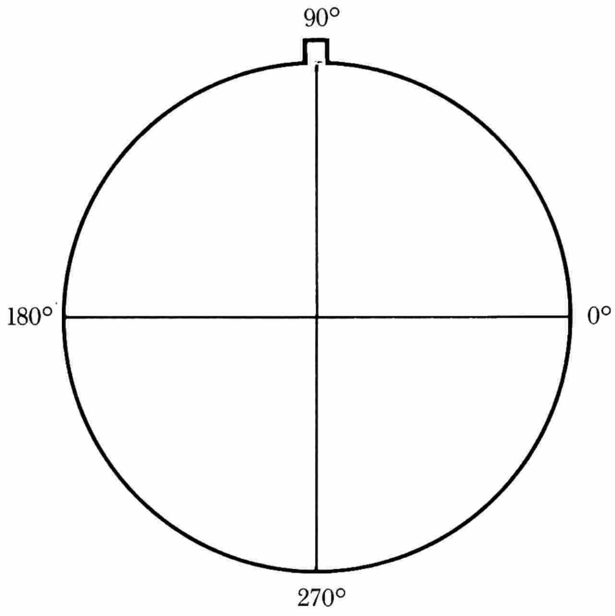


FIGURE 19.—Plate with tooth at 90°

FIGURE 20.—Astrolabe No. 2006. Handle pierced and fitted with a rotating pin.

inscription on the throne records a transfer of ownership.

One of the most interesting throne inscriptions appears on the astrolabe constructed by Muḥammad Mahdi in A.H. 1078 [A.D. 1667] (No. 25). It is a list of towns encircling a hole that once must have held a compass. The towns are arranged so that they proceed clockwise in order of increasing longitude. About half of the listed towns have longitudes less than the longitude of Mecca and about half have longitudes greater than that of Mecca.

The third category into which thrones from the mashriq may be grouped includes examples from all Persian schools of design. The early examples evidence the simplest taste (see Nos. 15 and 47). Decoration involving vines and flowers embossed on a stippled background characterizes instruments from the eighteenth century (see, e.g., Nos. 37 and 42.)

THE MAGHRIB

The thrones of astrolabes in the collection made in the maghrib add little bulk or decor. They are

small, generally less than half as high as they are wide. The earliest designs in the collection, those made before the fifteenth century (Nos. 144, 2572, 3643, 4001) are pierced with holes. Later examples (e.g., No. 2568) are solid and may carry inscriptions identifying the maker.

Europe

With a few notable exceptions (two in the collection, i.e., Nos. 2005 and 2007), the thrones of European astrolabes are unpretentious both in size and decoration. The latter generally consists of rosettes or scroll work. Inscription is rare. It occurs on only one instrument in the collection. On the back of the throne of astrolabe number 204, near the body, the word "Midi" has been engraved.

The two exceptionally elaborate thrones among the European instruments in the collection were designed in Italy (No. 2005) and France (No. 2007). The Italian example (made ca. A.D. 1580) incorporates a covered compass hole flanked by scroll-work. The French example (made ca. A.D. 1584) is decorated front and back with grotesque masks.

Front Rim

The Mashriq and Maghrib

Scales of Degrees

There are two types of degree scales. The first (1) is continuous (i.e., a single 360° scale). It appears on instruments from both regions. The second (2), known only from the mashriq, is really a group of four 90° scales.

Position: (1) The 360° scale extends from the 90° point clockwise around the rim back to the 90° point. (2) The 90° scales extend from (a) the 90° point clockwise around the rim to the 0° point (b), from there to the 270° point, (c) then from the 270° point to the 180° mark, and (d) finally from there back to the 90° point.

Units: The scales may be marked on the outer band every 5° with inscribed numerals and on the inner band at 1° intervals (uninscribed). Or they may be marked at 6° intervals with inscribed numerals and at 1° intervals (uninscribed).

Use: (1) The 360° scales are used with the *muri* (a marker on the ecliptic circle of the rete at 0° Capricorn) to measure the right ascension of the rising point of the celestial equator. (2) The 90° scales can be used with the alidade to measure either zenith distance (on arcs [a] and [c]) or altitude (on arcs [b] and [d]).

Remarks: (1) The instrument in the collection that carries the scale consisting of units of 6° apparently dates from the early twelfth century (No. 3643). It is inscribed with Kufic characters of the maghribi type. On all other Kufic instruments, this scale consists of units of 5°. In inscribing the 5° or 6° scales, some makers were quite explicit and wrote out all the digits of each designation from "5" (No. 2572) or "6" (No. 3643) to "360"; some, on the other hand, streamlined the process by implying the hundreds digit except in the designation of "100," "200," or "300" (No. 144). Further modification of this last method, whenever scales of 5° intervals were being inscribed, involved writing a "5" in the first and every other interval; thus: "5 10 5 20 5 . . . 300 . . . 5 60" (No. 4). A maker's decision to write out "360," or to drop the first digit, or to write "55" or "5" apparently depended on nothing more than individual taste. No national or time-based traditions reveal themselves. (2) The perception of this scale as a combination of four arcs of 90° is characteristic of seventeenth-century Indo-Persian astrolabes (Nos. 86, 87, 2569). It is also found on three eighteenth-century astrolabes (Nos. 47, 54, and 55) and on one astrolabe completed early in the nineteenth century (No. 53). All astrolabes incorporating this type of scale are engraved with Arabic *Naskhī*[68] characters. The scale is comprised of 6° divisions on three instruments (Nos. 53, 87, and 2569).

Altitude Scales

These 90° scales are found primarily on instruments made in the mashriq.

Position: These scales extend from the 0° point counterclockwise around the rim to the 90° point; from the 180° point clockwise to the 90° point;

from the 0° point clockwise to the 270° point; and from the 180° point counterclockwise to the 270° point.

Units: The scales are marked in units of 5°, inscribed with numerals (outer band), and 1° uninscribed (inner band), or 6°, inscribed with numerals, and 1° uninscribed.

Use: When used with the *muri*, these altitude scales measure the position of the vernal equinox relative to the zenith or nadir. (For the use with the alidade arm, see description of altitude scales on the back of the astrolabe, p. 30).

Remarks: Astrolabes in the collection with rim scales arranged in this way date from the late eighteenth and early nineteenth centuries (Nos. 58, 61, 62, 66). In every case of their appearance on the rim, the altitude scales duplicate similar scales on the back of the astrolabe. None of these instruments is equipped with a second alidade arm. The scale is divided into units of 6° on only one instrument, dating from the mid-eighteenth century (No. 66).

Europe

Winds

Position: This scale extends from the 90° point clockwise around the rim back to the 90° point.

Units: Marked in units equal to one-twelfth of a circle, inscribed with the names of the winds.

Use: This scale identifies direction (e.g., north, northeast) with the name of the wind associated with that direction (Septentrio, Aquilo).[69]

Remarks: Wind scales appear on two astrolabes in the collection, these being the instrument signed "Galois" (No. 204) and the instrument signed by Georg Hartman (No. 262). The named winds compare as follows:

Galois	*Hartman*
MERIDIES	AVSTER
LIBONOTVS	LIBONOTVS
APHRICVS	APHRICVS
OCCIDENS	FAVONIVS
CHORVS	CHORVS
CIRCIVS	CIRCIVS
SEPTENTRIO	SEPTENTRIO
BOREAS	AQUILO
VVLTVRNVS	CECIAS
ORIENS	SVBSOLANVS
EVRVS	VVLTVRNVS
EVROAVSTER	EVROAVSTER

Similar wind scales are incorporated into the design of horizontal sundials dating from the first and second centuries A.D.

Equal Hours

Position: This scale extends from the 90° point clockwise around the rim to the 270° point and from the 270° point back to the 90° point; or it extends from the 90° point clockwise around the rim back to the 90° point.

Units: 1 hour or 15° inscribed with numerals, and 12 minutes or 3° uninscribed, or 4 minutes or 1° uninscribed.

Use: A scale of equal hours is used with the index arm (or alidade) and the rete to indicate the time of day associated with a given configuration of the stars or the sun relative to the horizon.

Remarks: On two instruments in the collection, one signed "MP" (No. 221) and another apparently made in Italy (No. 186), the 24 divisions of the hour scale are inscribed with numbers from 1 to 24. On all other instruments, this scale is inscribed as two successive scales of 12 divisions. The scales inscribed by Hartman (No. 262) and Danfrie (No. 2007) use Roman numerals. All other astrolabists employed Hindu-Arabic numerals. All of the European instruments in the collection are fitted with an index arm or with an alidade, attached so that it can be used with the hour scale.

Scales of Degrees

Position: This 90° scale is marked in one of three ways. It extends from the 90° point clockwise around the rim to the 0° point; from the 90° point counterclockwise around the rim to the 180° point; from the 270° point clockwise around the rim to the 180° point; and from the 270° point counterclockwise around the rim to the 0° point. Or it extends from the 0° point counterclockwise around the rim to the 90° point; from

the 0° point clockwise around the rim to the 270° point; from the 180° point counterclockwise to the 270° point; and from the 180° point clockwise to the 90° point. Or it extends from the 90° point clockwise around the rim back to the 90° point.

Units: This scale is marked in units of 5° inscribed with numerals (outer band), or 10° inscribed with numerals, and 2° uninscribed.

Use: Degree scales in the first position were apparently designed to be used with an alidade to measure zenith distance. Degree scales in the second position were apparently designed to be used with an alidade to measure altitude. Degree scales in the third position were apparently designed to be used with the fixed index incorporated into the rete to measure the right ascension of the rising point of the celestial equator.

Remarks: The various methods of inscribing the scale of degrees are distributed as follows: scales in the first position appear on all European instruments in the collection, with the exception of that made by Georg Hartman (No. 262), who used the second position, and the early Italian astrolabe (No. 186), which includes a degree scale in the third position. Evidence in the collection suggests that the content of the rim was not as firmly established among European makers as it was among makers in the Muslim world.

Front Central Area

The Mashriq

Over half of the astrolabes in the collection have been inscribed with a list of cities along with their latitudes, longitudes, and one or more other geographic parameters (such as distance from Mecca). This list or gazetteer can invariably be found in the circular depression that constitutes the front of the body of a Persian or Indo-Persian instrument. Both very early (e.g., No. 15) and very late (No. 62) Persian astrolabes in the collection incorporate such a list.

For a number of reasons, an astrolabe's gazetteer can be considered to be one of its most interesting elements. First of all, its presence ties the astrolabe to an instrument-making tradition whose earliest surviving products include some portable sundials from antiquity. Both the so-called "Tischendorf Dial," dating from the fourth century, and the Aphrodisias Dial Plate, probably from the same period, are engraved with circular tables of places and their latitudes.[70] There is, then, at least a Byzantine precedent for Jaᶜfar ben ᶜUmar's inclusion (in A.D. 1372) of a circular table identifying each of a series of places with a longitude and latitude on a portable scientific instrument. The tables on the Byzantine dials proceed in order of increasing latitude; Jaᶜfar's table proceeds in order of increasing longitude.

While the form of an astrolabe's gazetteer relates it to portable sundials, its content relates it to a body of astronomical literature, the earliest example of which being "one of the most important astronomical documents of antiquity," Claudius Ptolemy's *προχειρων κανονων* (Handy Tables). One of these tables is a list of important cities (the *πόλεισ επισημοι*), with geographical latitudes and longitudes reckoned from the Fortunate Isles.[71] Variations on Ptolemy's theme were produced as astronomical *zij*es[72] by Arab authors, beginning in the early ninth century with the work of Yaḥya ben Abi Manṣur. These *zij*es typically contain (among other things) lists of cities and their geographical coordinates, tables of ecliptic coordinates of selections of "fixed" stars, and astrological tables of various kinds. Persian and Indo-Persian astrolabe makers almost certainly consulted *zij*es like Yaḥya's for the information necessary to complete *umm*, *ᶜankabūt*, and *ẓahr*. Publication of any one well-known *zij* could easily lead to the identification of astrolabes dependent upon it.[73] In the meantime, it will have to suffice to discuss the gazetteers of the instruments in the collection without knowing the exact source of their contents.

Jaᶜfar ben ᶜUmar's gazetteer (No. 15), inscribed in the fourteenth century, has been described above. The majority of cities included are located in what is now Iran (formerly Persia). Longitudes (*aṭwāl*), reported in degrees and minutes of arc, have been measured from the Fortun-

ate Isles. Latitudes (*ᶜurūḍ*), reported in degrees and minutes of arc, have been measured from the equator. The third recorded geographical parameter (*inḥirāf*), the inclination of the azimuth of the Qibla, is the measure of the arc of the horizon, reported in degrees and minutes, intercepted between the meridian of the listed city and a vertical circle passing through the zenith of Mecca. The data relating to each city seem to be arranged in order of increasing longitude beginning with Baghdad (80°00′) and ending with Samarqand (98°00′). Ibn Ash-Shaṭir published ca. A.D. 1350 a *zij* that included a list of 290 cities related to just the three geographical parameters included in Jaᶜfar's gazetteer. It is possible that Ibn Ash Shaṭir was Jaᶜfar's source of geographic data.

The gazetteer inscribed by ᶜAli ben ᶜAwaḍ al-Maḥmudi in the early seventeenth century (No. 70) is uniquely brief. It consists only of a list of 25 cities and their latitudes, grouped according to some geographic criteria that happen to preserve roughly modern national boundaries. The list places Mecca and Medina in successive places of honor,[74] a practice duplicated in almost all of the gazetteers containing these cities. One notable exception to the tendency to so distinguish these cities is the gazetteer inscribed in A.D. 1643 by the Indo-Persian maker Muḥammad Muqim (No. 86). The city of Lahore is given the place usually reserved for Mecca.

Indo-Persian astrolabe makers (at least in the seventeenth century), including Muḥammad Muqim, tended to limit the content of gazetteers to longitude and latitude. The practice, no doubt, reflects their limited appreciation of the importance of the Muslim religious center. Certainly they did not consider it to be an important geographic reference point. The geographic parameters which they do include apparently do not derive from a single *zij*.

The collection contains only one example (No. 44, the work of Muḥammad Mahdi) of a gazetteer inscribed with geographic parameters rounded to the nearest degree. A second astrolabe in the collection, dating from the late seventeenth century and inscribed by Qasim ᶜAli, is noteworthy because the information contained in its gazetteer includes at least the beginnings of a table of length of daylight.[75]

About half of the Persian (distinct from the Indo-Persian) gazetteers in the collection include a second table (in addition to the *inḥirāf*), which relates listed cities to Mecca. This second table, labeled *jihat* or *al-jihat*, gives the direction of the azimuth of the Qibla with respect to the four cardinal points. The entries in the table are "abbreviations," which can be interpreted as follows: SHSH is *Sharqi ash-Shamāl* or the northeast; SHJ is *Sharqi al-Janūb* or the southeast; GHJ is *Gharbi al-Janub* or the southwest; JAQ is *Janūb al-Qibla*, or south of the Qibla; SHAQ is *Shamāl al-Qibla*, or north of the Qibla. The latter two terms appear on instruments in the collection that date from the eighteenth or the nineteenth century. These terms do not occur in the two *jihat* tables on astrolabes dating from the seventeenth century. Both of these seventeenth-century instruments (Nos. 25 and 44) are ascribed to the maker-decorator Muḥammad Mahdi.

Figure 21 illustrates the gazetteer of the astrolabe decorated by Muḥammad Mahdi in A.D. 1667 (No. 25). Table 6 is a transcription of the contents. The selection and sequencing of cities apparent in this example can also be detected in the gazetteers of about 14 others in the collection (see, e.g., Nos. 31, 37, 39, 40, 42, 47, 49, 55, 57, 58, 59, 61, 62, 65). Undoubtedly all are derived from a single textual source, or *zij*.[76] The geographic parameters included in these gazetteers are similar enough to confirm a common heritage.

Astrolabe gazetteers which do not follow the tradition exemplified by Muḥammad Mahdi's instrument, at least in this collection, are those made most recently, i.e., in the nineteenth century. For example, the astrolabes signed by Muḥammad Ṣadiq (No. 52) and Ṣadiq (No. 53) contain similarly sequenced gazetteers, quite unlike Mahdi's. Astrolabes No. 2566 and No. 64 contain twin gazetteers that cannot be tied to either of the two Ṣadiqs or to the Mahdi instrument. The sequence of the contents of the gazetteer of the anonymous astrolabe No. 66 is unique

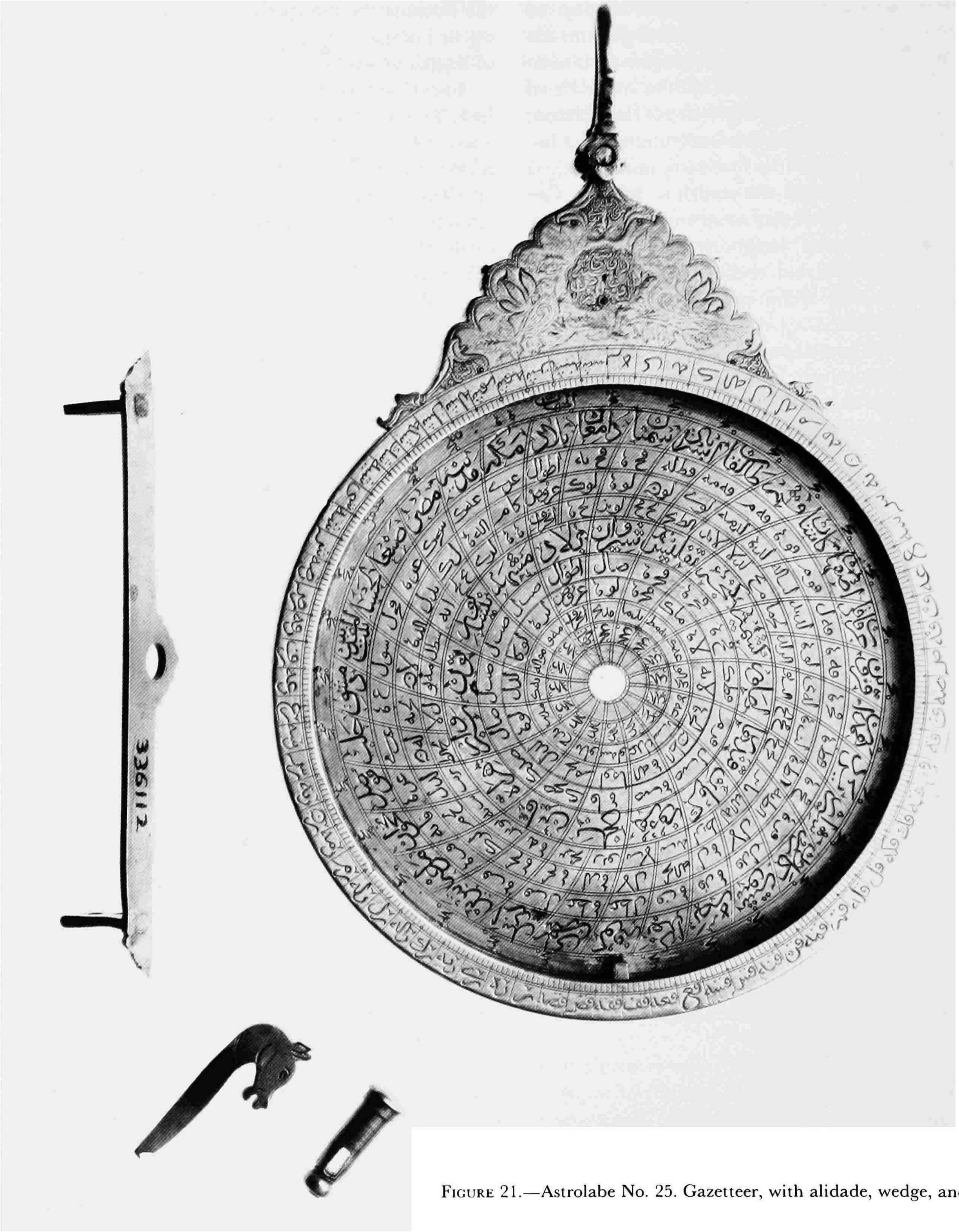


FIGURE 21.—Astrolabe No. 25. Gazetteer, with alidade, wedge, and pin.

TABLE 6.—Transcription of gazetteer inscribed on CCA No. 25

Place name	Geographic parameters			
	OUTER BANDS			
Bilad	*Aṭwal*	*ᶜArḍ*	*Inḥiraf*	*Al-jihat*
Mecca	77 10	21 40	00 00	00
Medina	75 20	25 00	37 10	SHJ
Miṣr	63 20	30 20	18 38	SHJ
Ṣanaᶜa	77 00	14 30	01 15	SHSH
Laḥsa	83 30	24 00	69 30	GHJ
Bait al-Maqdis	66 30	31 50	45 16	SHJ
Dimashq	70 00	33 15	30 31	SHJ
Ḥalab	72 10	35 50	18 29	SHJ
Moṣul	77 00	34 30	07 12	GHJ
Nakhijewan	81 15	38 40	12 15	GHJ
Maragheh	82 00	37 20	16 17	GHJ
Tabriz	82 00	38 00	15 00	GHJ
Ardabil	82 30	38 00	17 33	GHJ
Surra Man Raᵓa	79 00	34 00	07 16	GHJ
Kufa	79 30	31 30	12 31	GHJ
Baghdad	80 00	33 25	12 15	GHJ
Baṣra	84 00	30 00	37 19	GHJ
Shustar	84 30	31 30	35 24	GHJ
Kazerun	87 00	29 15	11 17	GHJ
Shiraz	88 00	29 00	33 38	GHJ
Yazd	89 00	32 00	48 28	GHJ
Hamadan	83 00	35 10	22 16	GHJ
Qazvin	85 00	36 00	27 34	GHJ
Gerfadman	85 30	34 14	33 41	GHJ
Iṣfahan	86 40	32 25	40 18	GHJ
Kashan	86 00	34 00	34 31	GHJ
Qom	85 40	34 45	31 14	GHJ
Ṭaliqan	85 45	36 10	29 13	GHJ
Asterabad	89 35	36 50	18 48	GHJ
Semnan	88 00	36 00	36 17	GHJ
Damghan	88 15	36 20	28 00	GHJ
	INNER BANDS			
Bilad	*Aṭwal*	*ᶜArḍ*	*Inḥiraf*	*Jihan*
Meshhad	92 30	37 00	45 06	GHJ
Nishapur	92 30	36 21	46 25	GHJ
Tun	92 30	34 30	55 20	GHJ
Sabzawar	91 30	36 00	44 12	GHJ
Herat	94 20	34 30	14 08	GHJ
Qayen	93 20	33 40	14 36	GHJ
Balkh	101 00	36 41	65 36	GHJ
Hormoz	92 00	25 00	74 30	GHJ
Kerman	92 30	29 50	62 11	GHJ
Qandahar	107 40	23 00	75 05	GHJ
Lahore	109 20	31 15	78 26	GHJ
Kashmir	88 00	31 00	75 20	GHJ
Ganjah	83 00	41 20	15 49	GHJ
Tiflis	83 00	43 00	14 41	GHJ
Shirwan	91 30	36 00	44 13	GHJ

in the collection. While the sequencing of all these gazetteers may differ from Mahdi's, the recorded geographic parameters are not significantly different. In all cases longitude has been reckoned from the Fortunate Isles.

Two nineteenth-century astrolabes in the collection (Nos. 63, 3811) include gazetteers that differ from Mahdi's not only in the sequencing of the selected cities but also in the reckoning of the geographic parameters. As the inscription on the throne of No. 63 explains, the longitudes have been reckoned from the Observatory of Greenwich, London. That these parameters were derived independently of the source for earlier parameters is suggested by the fact that no constant difference exists between the longitudes on No. 63 or No. 3811 and the longitudes on Mahdi's gazetteer. In addition, considerable differences exist in the latitudes recorded by Mahdi and the latitudes on Nos. 63 and 3811.

The gazetteer of Ṣadiq's astrolabe (No. 53) contains, in addition to longitude, latitude, and *inḥirāf*, an as yet undescribed scale called *al-masāfat*. This particular parameter is a measure of the arc of a great circle intercepted between the zenith of a listed city and the zenith of Mecca. On Ṣadiq's instrument this measure is given in *farsakhs*.[77] Ṣadiq's is the only instrument in the collection to contain this scale.

Appendix I includes a transcription of all gazetteers in the collection.

The Maghrib

Sterographic projections sometimes appear on the front central area of maghribi astrolabes. There are two types of such projections. The first (1) applies to the habitable latitudes. The second (2) applies to the Tropic of Capricorn (60°N) and the polar regions (90°N).

Position: This projection fills all four quadrants of the base plate.

Units: (1) See the section on plates (p. 47). (2) The projection is marked in units of 3° inscribed with numerals, or 6° inscribed with numerals (altitude and azimuth).

Use: (1) See the section on plates (p. 47). (2) A stereographic projection for the latitude of the Tropic of Capricorn 66°, when used with the ᶜ*ankabūt*, functions effectively as an indicator of celestial latitude and longitude. A stereographic projection for the North Pole, when used with the ᶜ*ankabūt*, functions effectively as an indicator of the celestial coordinates of right ascension and declination.

Remarks: (1) The two instruments in the collection that incorporate a plate projection into the *umm* were made in A.D. 1090 (No. 2572) and A.D. 1504 (No. 2571). The projections correspond to 37°30′ and 30°, respectively. (2) The two astrolabes in the collection containing polar projections were made in A.D. 1101 [?] (No. 3643) and 1304 (No. 144). The astrolabe containing a projection for latitude 66°N was made in A.D. 1224 (No. 4001).

Europe

Stereographic projections of habitable latitudes sometimes appear on European instruments.

Position: The projection of habitable latitudes fills all four quadrants of the base plate.

Units: See the section on plates (p. 47).

Use: See the section on plates.

Remarks: Most of the front central areas of European instruments in the collection are either blank or contain only the skeleton (tropics, equator, and solstitial and equinoctial colures) of a stereographic projection. Three instruments contain complete projections, however. For all three, this projection constitutes each instrument's only plate. The latitudes represented are 52° (Nos. 304 and 2006) and 48° (No. 204).

Back

The Mashriq

Altitude Scales

Position: These central circular scales extend from the 0° point counterclockwise around the

outer margin to the 90° point, and from the 180° point clockwise to the 90° point.

Units: The scale is marked every 5° inscribed with numerals (outer band) and 1° uninscribed (inner band), or 6° inscribed with numerals, and 2° uninscribed.

Use: The scale is used in conjunction with the alidade (see p. 6) to measure the height of the sun or of a well-known fixed star above the horizon.

Remarks: Two astrolabes in the collection, both apparently from Lahore in northern India (Nos. 87, 2569), have altitude scales divided into units of 2° and 6°.

Cotangent Scales

Position: These central circular scales (see Figure 1) extend from the 270° point clockwise around the outer margin to the 180° point, and from the 270° point counterclockwise to the 0° point.

Units: The scale is divided into "feet," inscribed with numerals and the identification *ẓill aqdām* (lower left), and "fingers," inscribed with numerals and the identification *ẓill aṣābiᶜ* (lower right).[78]

Use: The cotangent scales may be used as a nomogram (with the altitude scale and the alidade) to determine the altitude of the noon sun from the ratio between a gnomon of specific length (e.g., 7 feet or 12 fingers) and the length of its noon shadow (read on the cotangent scale). The scales are also useful for determining times of Muslim prayer defined by the ratio between a gnomon's length and the length of its shadow. The alidade is set at a shadow length appropriate for a given prayer, the astrolabe is hung plumb, and the prayer begun when a ray of sunlight passes between the pinholes of the alidade's sighting plates.

Remarks: The units adopted for this scale (or, more correctly, these two scales) have their origin in the *shadow table* tradition.[79] The use of 7- and 12-unit gnomons (feet and fingers) to compute such tables is known from Greek times. Hartner [80] clearly illustrates the relationship between this scale and a second foot or finger scale, the box tangent/cotangent scale (or shadow square), found on the back of the astrolabe. The latter can in a certain sense be viewed as an aid to the construction of the former. While the two scales can function independently, they tend to appear together. This is, in fact, the case for all but five of the astrolabes in the collection that are inscribed with Arabic characters. On only one of these exceptions (No. 4) does the circular scale stand alone. Hartner reports that scales divided into "feet" are most often found in the lower left quadrant of the astrolabe, while scales divided into "fingers" are most often found in the lower right. Indeed, most of the instruments in the collection (23 examples) follow Hartner's model. The 11 exceptions reverse the quadrants (feet lower right, fingers lower left). It is difficult to assign a reason for the difference, except to note that five of the nonconformists were made in western Persia or northern India.

Arc Scales

Position: The declination arcs are distributed in the upper right quadrant (see Figure 1). The arcs representing the azimuth of the Qibla are graphed on the declination arcs in the upper right quadrant between the 0° radius and the 45° radius. The arcs representing the altitude of the noon sun are graphed on the declination arcs in the upper right quadrant between the 45° radius and the 90° radius. The arcs representing equal or unequal hours are generally graphed onto the upper left quadrant, especially when other scales occupy the upper right. Prayer arcs are graphed onto the upper right quadrant when it contains the declination scale.

Units: The number of declination arcs varies from 6 (or one division for each sign of the zodiac) to 60 (or one division for each 1/10 sign of the zodiac). On some instruments the number of divisions varies from one sign of the zodiac to another. On most instruments the zodiacal segments are each divided by five arcs. Generally the

zodiacal segments are identified by name along the 0° radius and the 90° radius. Along the 0° radius the inscriptions indicate that the outer arc corresponds to the winter solstice and the inner arc corresponds to the summer solstice. The inscription along the 90° radius identifies the outer arc with summer and the inner arc with winter solstice. The number of arcs representing the azimuths of the Qibla varies from two to seven, each corresponding to a Middle Eastern city and inscribed with the name of that city. The arcs representing the altitude of the noon sun correspond to latitudes of position ranging from 22° to 50° and are inscribed with numerals. The hour arcs generally represent seasonal hours or 1/12 daylight, and are inscribed with numerals. The prayer arcs represent prayer times, inscribed *khaṭṭ ākhir al-ᶜaṣr* (line of end of afternoon prayer), *khaṭṭ awwal al-ᶜaṣr* (line of beginning of afternoon prayer), *khaṭṭ az-zawāl* (line of the going down of the sun), *khaṭṭ nisf an-nahār* (line of midday), or *awwal aẓ-ẓuhr* (beginning of a little time after midday). In some cases these inscriptions are modified by the designation of a specific latitude (e.g., *ᶜarḍ* 32).

Use: The declination arcs serve primarily as the context for other graphed scales. A declination scale without accompanying graphs does occur on one instrument in the collection (No. 47). The quality of workmanship on this particular example, however, suggests that the maker did not finish his work on the upper right quadrant. It is difficult to imagine a use for the declination arcs other than as context for graphs of azimuth, altitudes, hours, or prayers. The lines representing azimuths of the Qibla have been graphed on the declination arcs so that when the alidade of the astrolabe is placed at the point where the line for a city crosses the arc corresponding to the solar declination on a given day of the year, it marks on the altitude scale the altitude of the afternoon sun as it passes through the azimuth of the direction of Mecca from that city. The lines thus provide a means for determining the direction of Mecca from important centers of the Muslim world. The lines representing the altitude of the noon sun function nomographically in a manner analogous to the lines indicating the azimuth of the Qibla. The noon sun lines essentially aid in the determination of due south (the direction of the noon sun) for cities and towns at various latitudes.

As Henri Michel has explained,[81] the hour arcs can be considered a nomogram to be interpreted using the alidade in combination with the central circular altitude scale. Given the altitude of the noon sun, one can set the alidade at this altitude on the altitude scale and mark the point on the alidade arm which crosses the sixth hour arc. Measures of solar altitude made at any time on the given day can be related to a seasonal hour by observing the hour line coinciding with the mark made on the alidade corresponding to solar altitude measured at noon.

Prayer lines are used as a nomogram with the alidade and central circular altitude scale to associate solar altitude with times of Muslim prayer. Since each prayer line functions for a unique latitude, one might expect to find (as one does on examples in the collection) a latitude included as part of each inscribed identification.

Remarks: The declination arcs function equally well as a nomogram whether they result from stereographic projection or are equally spaced. Equally spaced arcs appear on four instruments in the collection (Nos. 42, 63, 70, 4000). It seems that the decision to employ one distribution rather than the other was purely a matter of taste. On most of the instruments in the collection the Qibla azimuth lines are arranged so that cities for which the angular distance between due South and the direction of Mecca is greatest appear lowest in the quadrant. In order to ensure that these Qibla lines will fall into the lower eighth of the quadrant, they are associated with declination circles identified by the scale along the 0° radius of the quadrant. In order to ensure that they will fall in the areas of the upper right quadrant between the 45° radius and the 90° radius, the altitude arcs are related to declination circles identified by the scale inscribed along the 90° radius. On no instrument in the collection

are prayer lines combined with other graphed arcs. Prayers are graphed on the declination arcs of six of the instruments in the collection made in the mashriq (Nos. 4, 70, 85, 86, 87, 88). The majority of these are of Indo-Persian origin.

Angle Scales

Position: These scales of sines and cosines occupy the upper left quadrant.

Units: These are the sines (and cosines) of angles that are multiples of 1° or 5° (see Figure 22), or sines (and cosines) of angles having sines (and cosines) that are multiples of 1/60 of the radius of the quadrant (see Figure 23).

Use: Sines (and cosines) distributed according to multiples of degrees are used with an alidade which is graduated so that it can measure off a given vertical (or horizontal) component of a sine (or cosine) to be related to an angle which can be read from the altitude scale. Sines (and cosines) distributed according to multiples of 1/60 of the quadrant radius require an alidade to measure an angle to be related to a sine or cosine, which can be read directly from the scale. The former distribution would be most useful in cases where the trigonomic function is known and its corresponding angle is to be found. The latter scale would be more useful when the angle is known and its sine or cosine is to be found.

Remarks: Sines and cosines which divide the quadrant into 60 parts are found on astrolabes in the collection more often than sines and cosines related to multiples of degrees. Only seven instruments exhibit the latter configuration (Nos. 15, 25, 39, 47, 54, 55, and 70). On a few of the astrolabes in the collection, the quadrant containing the cross-hatching of trigonometric parts also contains radii evenly dividing the quadrant (Nos. 58, 63, and 70) or concentric quarter circles corresponding to the solar declination at various times of year (Nos. 47, 52, and 85). On six examples, the unequal hours also divide the trigonometric quadrant (Nos. 25, 39, 54, 55, 57, and 59). On two other examples (Nos. 53 and 4000) only a noon line appears (a semi-circle with diameter equal to the quadrant radius).

Box Scales

These examples of tangent scales (a and d) and cotangent scales (b and c) can be seen in Figure 1.

Position: The tangent scales extend vertically from the radius at 180° to the radius at 225°, and from the radius at 0° to the radius at 315°. The cotangent scales extend horizontally from the radius at 270° to the radius at 225° and from the radius at 270° to the radius at 315°.

Units: These scales are marked in "feet," inscribed with numerals and identified as *ẓill aqdām maᶜkūs* (a in Figure 1) and *ẓill aqdām mustawī* (b in Figure 1); and "fingers," inscribed with numerals and identified as *ẓill aṣābiᶜ mustawī* (c in Figure 1) and *ẓill aṣābiᶜ maᶜkūs* (d in Figure 1).

Use: See section on central circular cotangent scales (p. 31), and note that the tangent scale has a use when the altitude of the noon sun is less than 45°; the cotangent scale should be used when the altitude of the noon sun is greater than 45°

Remarks: Judging from the examples of their work in this collection, maker-decorator ᶜAbd al-Aʾimma (Nos. 37, 39, and 40) and maker Muḥammad Mahdi (Nos. 25 and 44) preferred to abbreviate the identification of each cotangent scale to *mustawi*. For related remarks see the section on central circular cotangent scales (p. 31).

Circular Tables

Position: The tables extend from the 180° point on the astrolabe counterclockwise to the 0° point (see Figure 24).

Units: These tables are marked according to the following: astrological term or limit, 1/60 of a semicircle, inscribed with the name or the last letter of the Arabic name of one of the five visible planets that governs the term (generally the outermost band; see Table 7); astrological term or limit, 1/60 of a semicircle, inscribed with numerals from 6 to 30, representing term boundaries within zodiacal signs (generally the band just inside the band of planetary governors of the terms; see Table 7); zodiacal sign, 1/12 of a

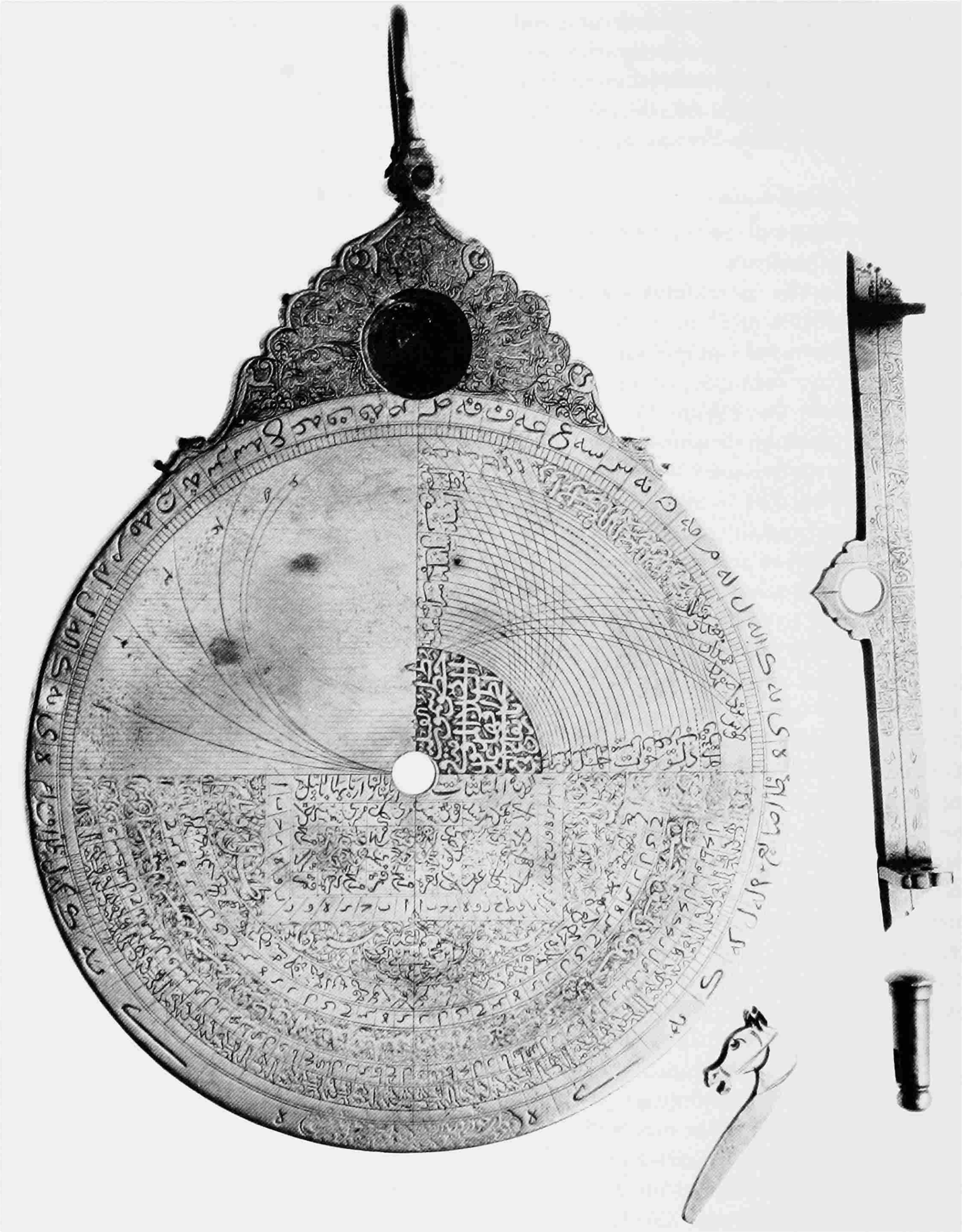


FIGURE 22.—Astrolabe No. 25. Upper left quadrant includes sines of angles, which are multiples of 1°

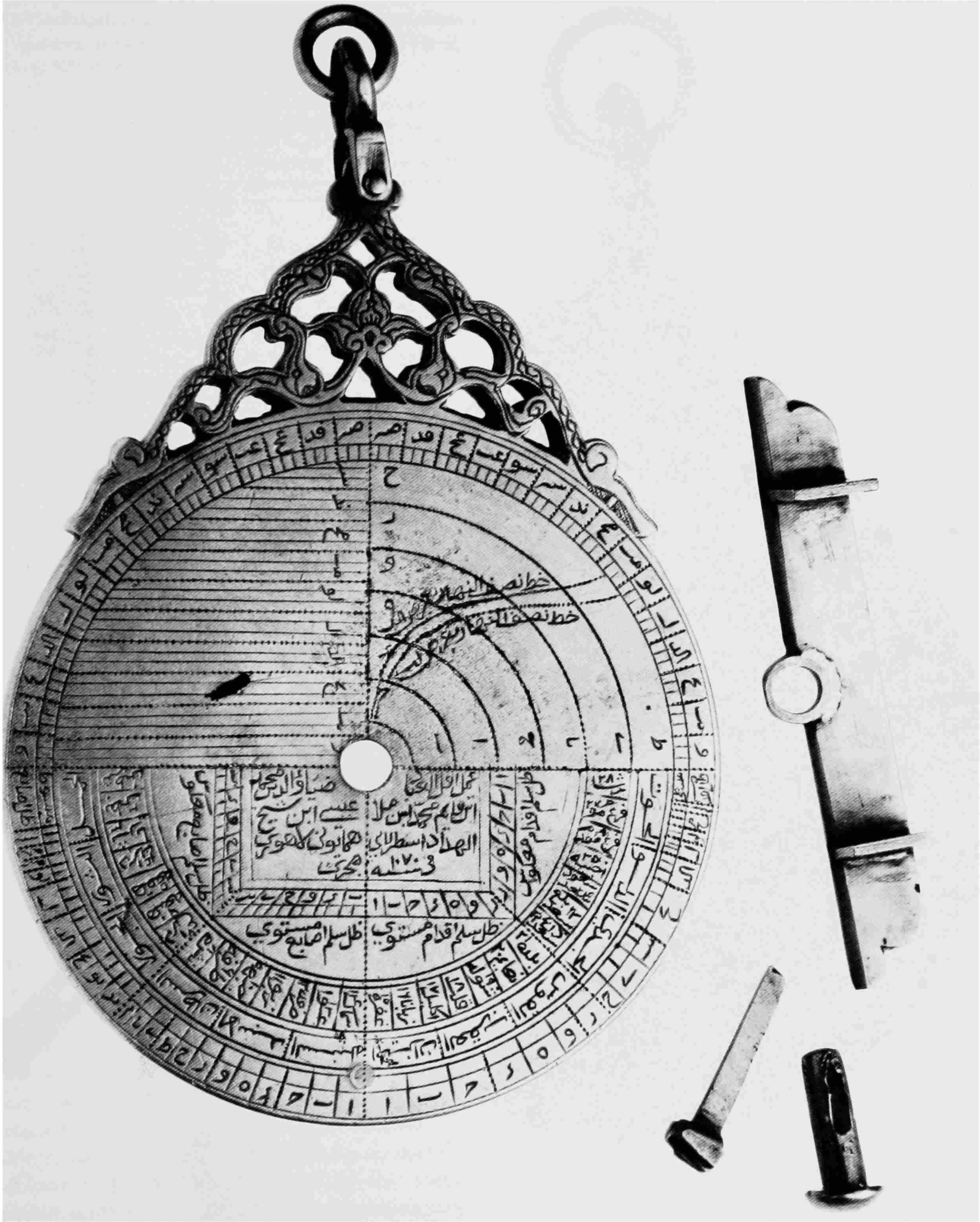


FIGURE 23.—Astrolabe No. 87. Upper left quadrant includes sines, which are multiples of 1/60 of the radius of the quadrant.

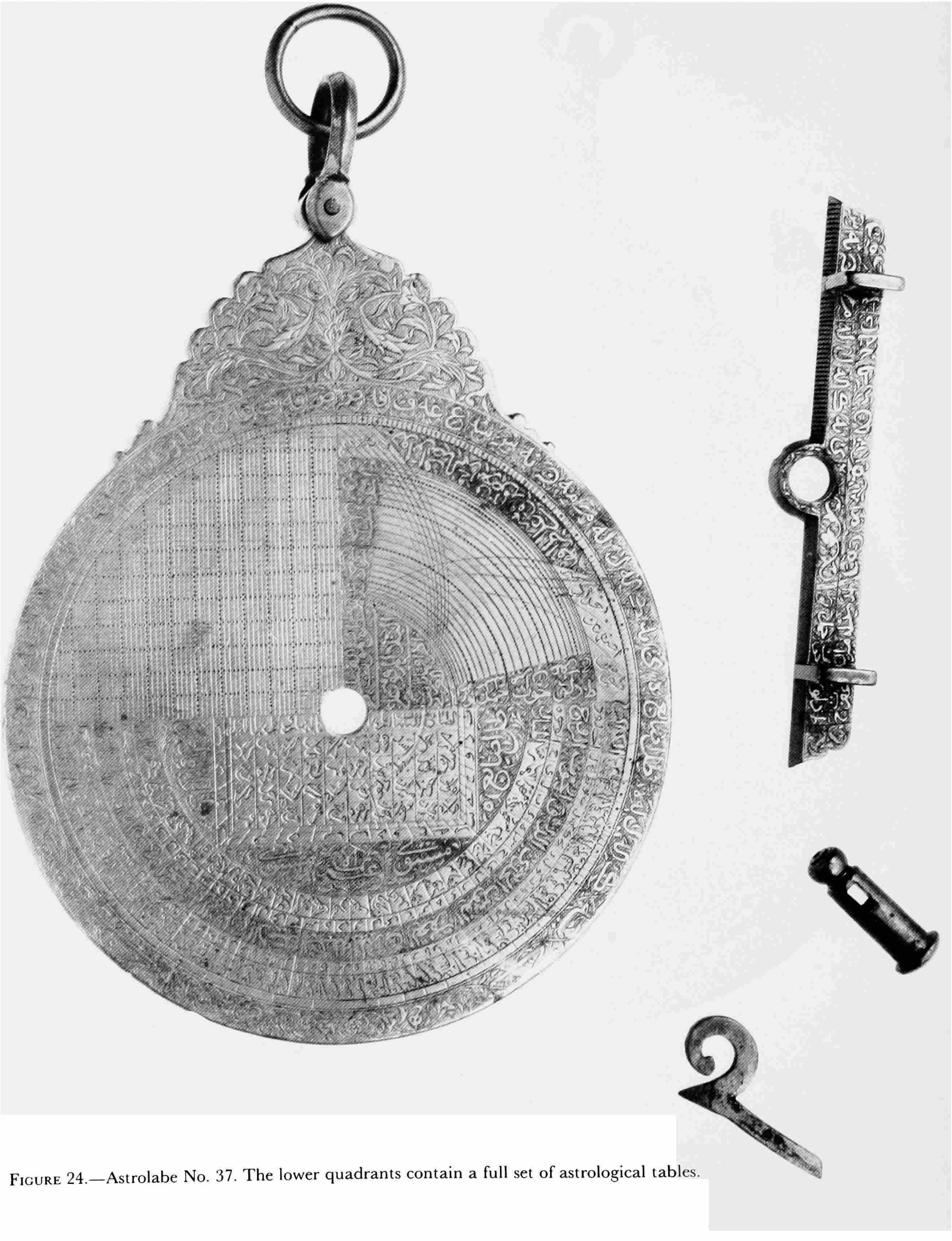


FIGURE 24.—Astrolabe No. 37. The lower quadrants contain a full set of astrological tables.

TABLE 7.—Planetary governors and degree divisions of terms (I = *Mushtari*, Jupiter; H = *Zuharah*, Venus; D = *ᶜUṭarid*, Mercury; KH = *Mirrikh*, Mars; L = *Zuḥal*, Saturn)

Zodiacal Signs 0–5		Zodiacal Signs 6–11	
Planetary governors	Degree divisions	Planetary governors	Degree divisions
I	6	L	6
H	12	D	14
D	20	I	21
KH	25	H	28
L	30	KH	30
H	8	KH	7
D	14	H	11
I	22	D	19
L	27	I	24
KH	30	L	30
D	6	I	12
I	12	H	17
H	17	D	21
KH	24	L	26
L	30	KH	30
KH	7	D	7
H	13	I	14
D	19	H	22
I	26	L	26
L	30	KH	30
I	6	D	7
H	11	H	13
L	18	I	20
D	24	KH	24
KH	30	L	30
D	7	H	12
H	17	I	16
I	21	D	19
KH	28	KH	28
L	30	L	30

semicircle, inscribed with the Arabic name of each sign of the zodiac (generally the third band from the outside; see Table 8); astrological face, 1/36 of a semicircle, inscribed with the Arabic name or the last letter of the name of the sun, moon, or one of the five visible planets that governs the face (fourth band from outside; see Table 9); and lunar mansion, 1/28 of a semicircle, inscribed with the Arabic name of the lunar mansion (innermost band; see the accompanying tabulation, *Lunar Mansions*).

Use: The term tables associate the five visible

TABLE 8.—Zodiacal signs

Number	Name	
	English	Arabic
0	Aries	*al-Ḥamal*
1	Taurus	*al-Thawr*
2	Gemini	*al-Jawzā*
3	Cancer	*as-Saraṭān*
4	Leo	*al-Asad*
5	Virgo	*as-Sunbula*
6	Libra	*al-Mīzān*
7	Scorpio	*al-ᶜAqrab*
8	Saggitarius	*al-Qaws*
9	Capricorn	*al-Jady*
10	Aquarius	*al-Dalw*
11	Pisces	*al-Ḥūt*

planets with unequal divisions of each zodiacal sign. The zodiacal signs are associated with the terms and the faces. The faces table associates a visible planet or the sun or moon with each 10° division of the zodiac. The table of lunar mansions specifies yet another division of the heavens.

LUNAR MANSIONS

Sharāṭan	*Nathrah*	*Ghafr*	*Dhābih*
Buṭain	*Ṭarfah*	*Zubāna*	*Bulaᶜ*
Thurayya	*Jabhah*	*Iklil*	*Suᶜūd*
Dabarān	*Zubrah*	*Qalb*	*Akhbiyya*
Haqᶜah	*Ṣarfah*	*Shaula*	*Muqaddam*
Hanᶜah	*ᶜAwwa*	*Naᶜāʾim*	*Muʾakhkhar*
Dhirāᶜ	*Simāk*	*Baldah*	*Rishsha*

Remarks: All of the collection's astrolabes containing term tables indicate a preference for a system of association between planets and zodiacal divisions that Ptolemy attributes to Egyptian astrologers.[82] On two of these (Nos. 4 and 2569) the numbers on the inner term table indicate the number of degrees in each division of a zodiacal sign rather than the position of each division point within the sign. Only one astrolabe in the collection contains in addition to a table of faces a semicircular table of thirds of a sign, called (by Hindus according to al-Biruni)[83] *decanates*. This relatively rare example was signed in Western Kufic characters by Jaᶜfar ben ᶜUmar (No. 15).

TABLE 9.—Planetary governors (first row) and degree divisions (second row) of astrological faces (KH = *Mirrikh*, Mars; S = *Shams*, Sun; H = *Zuharah*, Venus; D = ᶜ*Uṭarid*, Mercury; R = *Qamar*, Moon; L = *Zuḥal*, Saturn; I = *Mushtari*, Jupiter)

KH	S	H	D	R	L	I	KH	S	H	D	R
10	20	30	10	20	30	10	20	30	10	20	30

L	I	KH	S	H	D	R	L	I	KH	S	H
10	20	30	10	20	30	10	20	30	10	20	30

D	R	L	I	KH	S	H	D	R	L	I	KH
10	20	30	10	20	30	10	20	30	10	20	30

Rectangular Tables

Position: A table of triplicities fills the shadow square (if any) in the lower left and lower right quadrants. Generally it consists of five rows (the upper one of which contains the table name) and ten columns (see Table 10).

Units: Signs of the zodiac inscribed with numerals or names and associated with planetary lords, each identified by the last letter of its Arabic name and each associated with one of the Aristotelian elements: earth, air, fire, or water.

Use: The table associates those signs of the zodiac which are situated in the zodiac at the angles of equi-angled triangles and records the nature of each *trigon* thus formed. In addition, the table associates planets with similar "natures" with each trigon.[84]

Remarks: The triplicity scale on No. 2569 fills the lower left shadow square only. The inscriptions that specify the nature of each trigon (fiery, earthy, airy, watery) can be used to delineate subgroups of astrolabes carrying this table. The four words that can be recognized as "Arabic" terms for these natures appear consistently on astrolabes made in Iṣfahan. At least two instruments (Nos. 55 and 85) carry what Morley calls the "Persian" terms for these natures.[85] Some instruments (e.g., No. 58) seem to carry a mixture of "Arabic" and "Persian" terminology.

THE MAGHRIB

Altitude Scales

Position: These circular scales are centered on the instrument (see the section on "The Mashriq," p. 30).

Units: See section on "The Mashriq."

Use: See section on "The Mashriq."

Remarks: On No. 3643 the altitude scale is continued into the lower quadrants of the astrolabe back. These additions extend from the 180° point counterclockwise to the 270° point, and from the 0° point clockwise to the 270° point.

Cotangent Scales

Position: These circular scales are centered on the instrument. They extend from the 225° point clockwise approximately to the 190° point, and from the 225° point counterclockwise approximately to the 253° point; also from the 315° point clockwise approximately to the 287° point, and from the 315° point counterclockwise approximately to the 343° point.

TABLE 10.—Planetary lords, zodiacal signs, and natures of the triplicities (L = *Zuḥal*, Saturn; S = *Shams*, Sun; KH = *Mirrikh*, Mars, H = *Zuharah*, Venus; I = *Mushtari*, Jupiter, D = ᶜ*Uṭarid*, Mercury, R = *Qamar*, Moon)

Planetary lords						Zodiacal signs			Natures
L	S	I	L	I	S	Saggitarius	Leo	Aries	Fiery
KH	H	R	KH	R	H	Capricorn	Virgo	Taurus	Earthy
I	L	D	I	D	L	Aquarius	Libra	Gemini	Airy
R	H	KH	R	KH	H	Pisces	Scorpio	Cancer	Watery

Units: These scales are divided into "fingers" or arcs of a circle (with center at the center of the astrolabe) bounded by radii that mark off lengths along the extended horizontal scale of the shadow square. The arcs are inscribed with numerals specifying the length marked by the radii, measured in units equal to 1/12 of the shadow square's gnomon (see Figure 2).

Use: See section on "The Mashriq" (p. 31).

Remarks: On No. 4001 this scale is identified with the inscription *ṣah(?) aṣābiᶜ aẓ-ẓillayn.* If the astrolabes in this collection are representative, it appears that this scale is often omitted entirely from examples made in the maghrib.

Zodiacal Tables

Position: The table extends counterclockwise through 360°, starting at the 0° point.

Units: This table is, inscribed with numerals every 5°, and inscribed with the names of the zodiacal signs at 30° intervals.

Use: The table is combined with a circular calendar table and the alidade to read the longitude of the sun for a given calendar date.

Remarks: All non-European astrolabes in the collection having a complete 360° central circular zodiac table originated in the maghrib.

Calendar Tables

Position: The table extends counterclockwise 360° from a beginning point (representing 1 January), which varies in position from 286° to 292°.

Units: The table consists of one-day units uninscribed on the outer band, and five- to six-day units inscribed with numerals (central band), and one-month units, inscribed with month names (inner band).

Use: Combined with a circular table of zodiacal signs and the alidade, this table is used to read the longitude of the sun given the date.

Remarks: All non-European astrolabes carrying a circular calendar originated in the maghrib and are associated with a 360° central circular zodiac table. Two relatively early non-European astrolabes (Nos. 144 and 304) contain eccentrically-centered calendar tables (see Figure 25).

TABLE 11.—Solar cycle (1 = Sunday, 2 = Monday, etc.)

Year	Day of the week	Leap year indicator	Year	Day of the week	Leap year indicator
1	3		15	7	
2	4	K	16	1	
3	6		17	2	
4	7		18	3	K
5	1		19	5	
6	2	K	20	6	
7	4		21	7	
8	5		22	1	K
9	6		23	3	
10	7	K	24	4	
11	2		25	5	
12	3		26	6	K
13	4		27	1	
14	5	K	28	2	

The remaining calendar tables on instruments originating in the maghrib (Nos. 2568, 2571, 3643, and 4001) are concentric with the zodiac table. On both maghribi instruments with eccentrically centered calendar tables, the radial position of the apsidal line (the line connecting the centers of the zodiacal and calendar tables) is about 75°. On one maghribi astrolabe in the collection (No. 4001) a series of central circular scales relates a day in the week (represented by the numerals 1 to 7) to a date in the Julian calendar. The table (see Table 11) reflects the fact that the day of the week of the first of January advances one day every year, except following a leap year, when it advances two days (365 leaves a remainder of 1 upon division by 7). The pattern of possible first days repeats after 28 years (7 days × 4 years). The count of years is often called the *solar cycle.*

Arc Scales

The arc scales on maghribi instruments are usually confined to scales of hours. See the discussion of mashriqi arc scales (p. 31).

Box Scales

Position: See description under "The Mashriq," (p. 33).

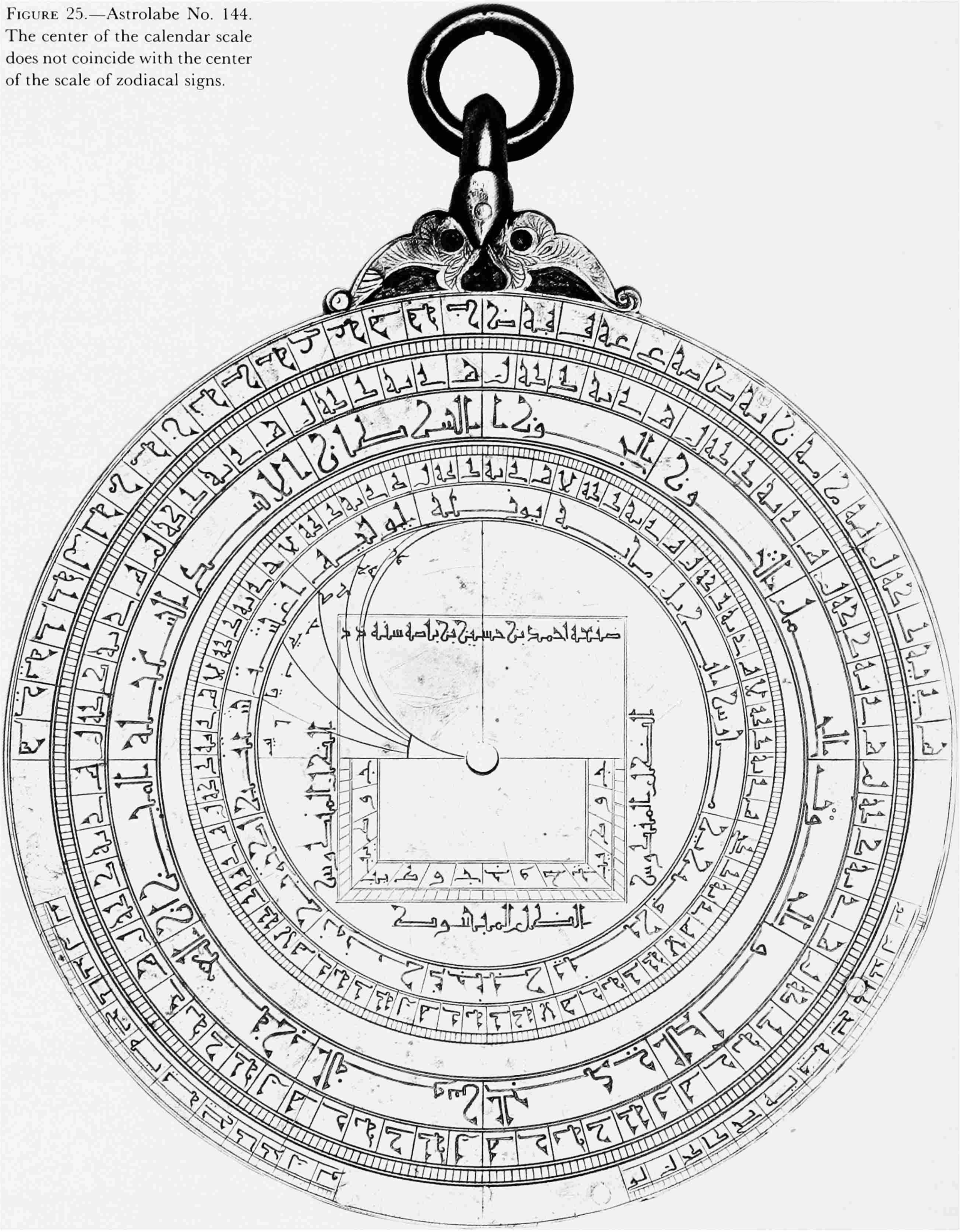


FIGURE 25.—Astrolabe No. 144. The center of the calendar scale does not coincide with the center of the scale of zodiacal signs.

Units: These scales are marked in fingers, inscribed with numerals, and identified by the inscription *aẓ-ẓill al-ma ʿkūs* and *aẓ-ẓill al-mabsūṭ*.

Use: See the section on "The Mashriq" (p. 33).

Remarks: Two characteristics distinguish the box scale on the maghribi instruments in this collection from the examples originating in the mashriq: the scales are divided into fingers only, and the cotangent scale is identified with the term *mabsūṭ* (extended) instead of *mustawī* (level).

Europe

Altitude Scales

Position: These circular scales are centered on the instrument. They extend from the 0° point counterclockwise to the 90° point, and from the 180° point clockwise to the 90° point, and from the 180° point counterclockwise to the 270° point, and from the 0° point clockwise to the 270° point.

Units: See section on "The Mashriq" (p. 31).

Use: See section on "The Mashriq" (p. 31).

Remarks: The altitude scale on one European instrument in the collection (No. 2007) can be read to within half a degree. This is the paper astrolabe by Danfrie. The units of the altitude scale on the "de Roias" instrument in the collection (No. 2005) are 10° inscribed with numerals, and 2° uninscribed.

Zodiac Tables

Position: See section on "The Maghrib" (p. 39).

Units: See section on "The Maghrib."

Use: See section on "The Maghrib" (p. 39).

Remarks: The 5° divisions on the astrolabe signed by Hartman (No. 262) are marked with Roman numerals.

Calendar Tables

Position: The scale extends counterclockwise 360° from a beginning point which varies from 279° to 291° (see Figure 26).

Units: The scale is divided into units of one day, uninscribed, and 4–11 days, inscribed with numerals, and one month, inscribed with month names.

Use: See section on "The Maghrib" (p. 39).

Remarks: About half of the calendars on the cataloged European instruments have eccentric centers on apsidal lines at 90° The paper astrolabe in the collection (No. 2007) contains in addition to the calendar a set of tables designed to facilitate the determination of the date of Easter. The first of these is a table (see Table 12) of the solar cycle associated with a dominical letter. (On No. 2007, this table is a small circular scale in the upper left quadrant of the astrolabe back.) The dominical letter is a letter from A to G associated with the first Sunday of the year. Assignment of the letter A to the first Sunday

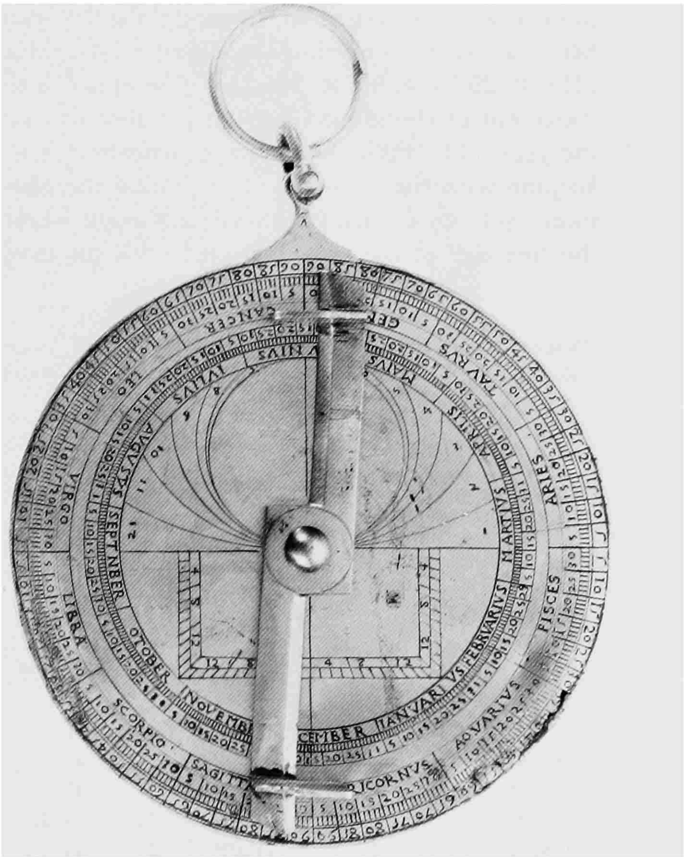


FIGURE 26.—Astrolabe No. 186. The date of the vernal equinox (Aries 0°) is 10.5 March.

indicates that it is the first day of the year; B, that it is the second day, and so on. It should be apparent that the pattern of dominical letters repeats after 28 years in the same way that the pattern of days of the week associated with January first repeats. Hence, the dominical letters are found in conjunction with the so-called solar cycle. (See the discussion of a related table in the section on central circular scales found on maghribi astrolabes, p. 39). Note that leap years in the cycle are indicated by two dominical letters. The letter on the right is that corresponding to the first Sunday of the year. That letter corresponds to subsequent Sundays of the year until the leap day is intercalated when the "dominical" letter becomes the one on the left.

A second circular table (see Table 13) found on the paper astrolabe (No. 2007) relates the golden number, the epact, and the paschal index (see Figure 27). The golden number is nothing more than a reference to a year in the 19-year Metonic cycle connecting lunar and solar cycles ($235 \times 29.53 \cong 19 \times 365.25$). The epact is a statement of the moon's age on the first day of the year. (The table on the paper astrolabe is in keeping with the tradition of beginning the Metonic cycle [or golden numbers] at a point when the first day of the year coincides with the new moon.) Note that each epact is 11 days later than the one preceding, reflecting the fact that the lunar year ($12 \times 29.5 = 354$ days) is 11 days shorter than the solar year. The paschal index is the date of the first full moon falling on or following after the vernal equinox (21 March in the Gregorian calendar).

TABLE 12.—Solar cycle and associated dominical letter (taken from CCA No. 2007; extrapolated dates in brackets)

Year A.D.	Solar cycle	Dominical letter	Year A.D.	Solar cycle	Dominical letter
[1568]	1	F, G	[1582]	15	C
[1569]	2	E	1583	16	B
[1570]	3	D	1584	17	G, A
[1571]	4	C	1585	18	F
[1572]	5	A, B	[1586]	19	E
[1573]	6	G	[1587]	20	D
[1574]	7	F	[1588]	21	B, C
[1575]	8	E	[1589]	22	A
[1576]	9	C, D	[1590]	23	G
[1577]	10	B	[1591]	24	F
[1578]	11	A	[1592]	25	D, E
[1579]	12	G	[1593]	26	C
[1580]	13	E, F	[1594]	27	B
[1581]	14	D	[1595]	28	A

TABLE 13.—Paschal index and epact with related golden number

Year A.D.	Paschal index	Epact	Golden number
[1577]	12 Apr	I	1
[1578]	1 Apr	XII	2
[1579]	21 Mar	XXIII	3
[1580]	9 Apr	IIII	4
[1581]	29 Mar	XV	5
[1582]	17 Apr	XXVI	6
1583	6 Apr	VII	7
1584	26 Mar	XVIII	8
1585	14 Apr	XXIX	9
[1586]	3 Apr	X	10
[1587]	23 Mar	XXI	11
[1588]	11 Apr	II	12
[1589]	31 Mar	XIII	13
[1590]	18 Apr	XXIIII	14
[1591]	8 Apr	V	15
[1592]	28 Mar	XVI	16
[1593]	16 Apr	XXVII	17
[1594]	5 Apr	VIII	18
[1595]	25 Mar	XXIX	19

The third table in the series is a central circular table adjacent to the calendar (see Table 14). Although it is not identified on No. 2007, the table is commonly referred to as the "Gregorian Calendar of Epacts." It enables the user to predict the dates of the new moon for any year, given its epact. The epacts are distributed so that they fall next to the date that would correspond to the new moon if the moon was the age of the epact on 1 January. Sometimes two epacts fall on the same day in order to allow for the circumstances that some synodic months have 30 days and some have 29. (In a year with epact 25, new moons fall on the dates opposite 25 if the golden number is less than 11, and on dates opposite 25′ if the golden number is greater than 11.)

Note that the maker of astrolabe No. 2007 included the years A.D. 1583, 1584, and 1585 at

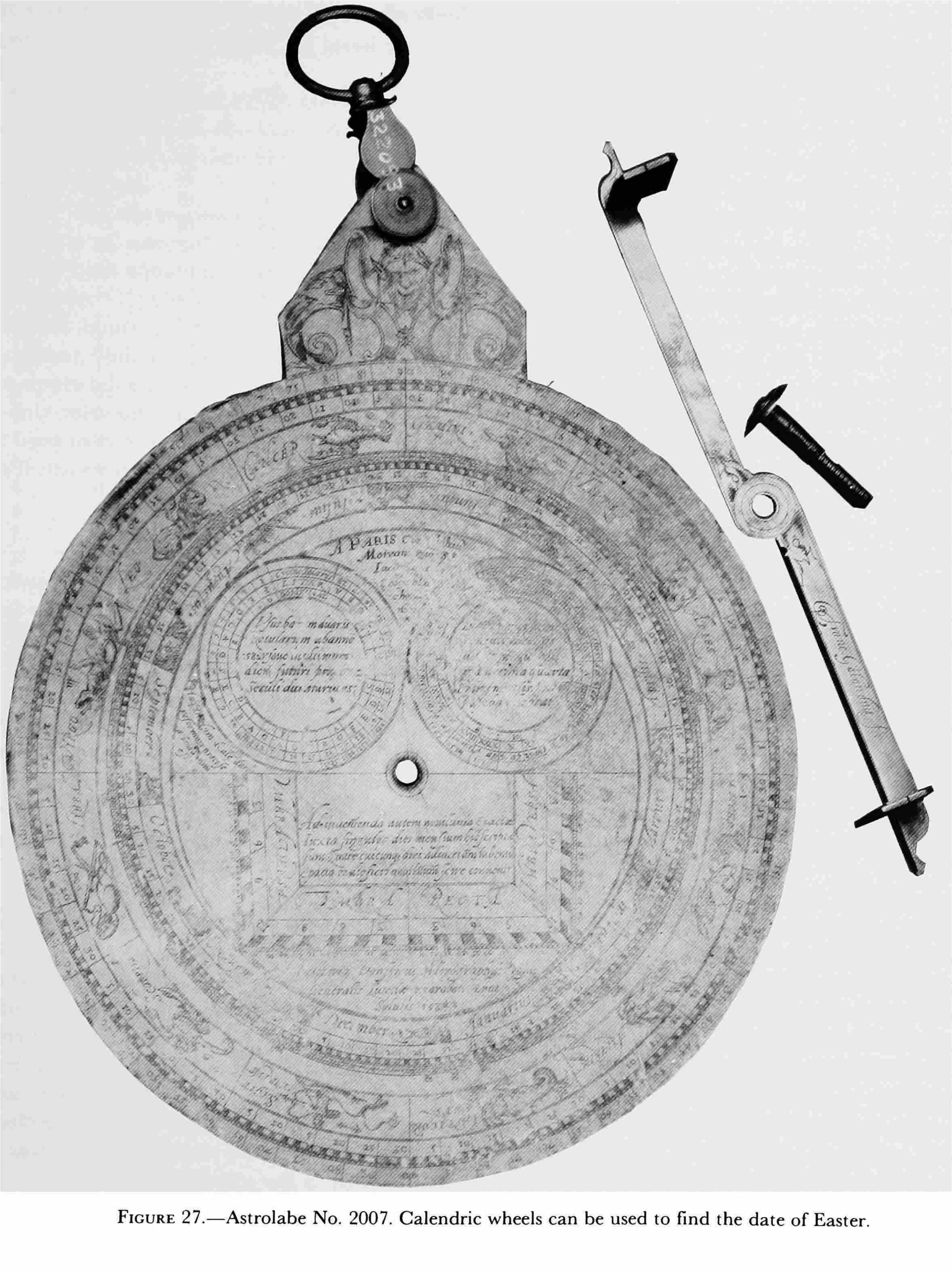


FIGURE 27.—Astrolabe No. 2007. Calendric wheels can be used to find the date of Easter.

Table 14.—Gregorian calendar of epacts

Count of days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1		29		29	28	27	26	25 24	23	22	21	20
2	29	28	29	28	27	25′26	25′25	23	22	21	20	19
3	28	27	28	27	26	25 24	24	22	21	20	19	18
4	27	25′26	27	25′26	25′25	23	23	21	20	19	18	17
5	26	25 24	26	25 24	24	22	22	20	19	18	17	16
6	25′25	23	25′25	23	23	21	21	19	18	17	16	15
7	24	22	24	22	22	20	20	18	17	16	15	14
8	23	21	23	21	21	19	19	17	16	15	14	13
9	22	20	22	20	20	18	18	16	15	14	13	12
10	21	19	21	19	19	17	17	15	14	13	12	11
11	20	18	20	18	18	16	16	14	13	12	11	10
12	19	17	19	17	17	15	15	13	12	11	10	9
13	18	16	18	16	16	14	14	12	11	10	9	8
14	17	15	17	15	15	13	13	11	10	9	8	7
15	16	14	16	14	14	12	12	10	9	8	7	6
16	15	13	15	13	13	11	11	9	8	7	6	5
17	14	12	14	12	12	10	10	8	7	6	5	4
18	13	11	13	11	11	9	9	7	6	5	4	3
19	12	10	12	10	10	8	8	6	5	4	3	2
20	11	9	11	9	9	7	7	5	4	3	2	1
21	10	8	10	8	8	6	6	4	3	2	1	
22	9	7	9	7	7	5	5	3	2	1		29
23	8	6	8	6	6	4	4	2	1		29	28
24	7	5	7	5	5	3	3	1		29	28	27
25	6	4	6	4	4	2	2		29	28	27	26
26	5	3	5	3	3	1	1	29	28	27	25′26	25′25
27	4	2	4	2	2			28	27	26	25 24	24
28	3	1	3	1	1	29	29	27	25′26	25′25	23	23
29	2		2			28	28	26	25 24	24	22	22
30	1		1	29	29	27	27	25′25	23	23	21	21
31					28		25′26	24		22		19′20

appropriate places in the calendric tables. These are crucial years following the Gregorian reform. These specialized calendric tables were undoubtedly used to compute the date of Easter, a rather involved procedure with or without the help of tables. For example, to find the date of Easter in A.D. 1584, one would consult Table 13 to find that year's golden number (8), epact (18), and paschal index (26 March). Knowing that Easter would be the first Sunday following 26 March, one would consult Table 12 to find the dominical letter. In 1584, Sunday was the first day of the year (day A). By counting by sevens from 1 January on the calendar scale (and remembering that February has 29 days in 1584), one would find the first Sunday following 26 March to be 1 April, Easter Sunday.

Non-calendric tables are rarely to be found on astrolabes of European origin. Only one European instrument in this cataloged collection (No. 204) contains such a table, and that is a table of star names, which also gives their longitude, magnitude, "mediation" (see page 56), and declination. In this example, the stars named are exactly those included in the rete design.

Arc Scales

Position: The scales of unequal or seasonal hours (1) are generally distributed in the upper

left and upper right quadrants. The scale of equal hours (2) occupies the upper left quadrant of No. 221.

Units: The seasonal hours are inscribed with numerals. The equal hours are marked in units equal to 1/24 of the time between meridian passages of the sun.

Use: See the section on "The Mashriq" for a discussion of unequal hours, which may be applied to both equal and unequal hours.

Remarks: (1) On astrolabe No. 221 the scale of unequal hours is confined to the upper right quadrant, with a scale of equal hours graphed in the upper left quadrant. (2) Any equal hour scale is only relevant for one latitude.[86] This fact can be used to establish the place of intended use for an instrument of otherwise uncertain origin.

Box Scales

Position: The shadow square, the box scale that appears on almost all astrolabes, is discussed in the section on "The Mashriq" (p. 33).

Units: This scale is marked in units of one finger, uninscribed, and two, three, or four fingers, inscribed with numerals and identified *Umbra Recta* (horizontal scales) and *Umbra Versa* (vertical scales). It may also be marked at every sexagesimal unit, uninscribed, and five sexagesimal units, inscribed with numerals.

Use: See section on "The Mashriq" (p. 33).

Remarks: Whereas the box scales are identified by name on every instrument containing them originating in the mashriq or maghrib, such titles are omitted from box scales on two European instruments in the collection (Nos. 186 and 304). Both of the latter are attributed to fifteenth-century makers. On one other European example (No. 2006) the box scales are inscribed *Corda Recta* and *Corda Versa*.

Special Projections

THE QUADRANT.—*Position and Units:* A special projection on the back of one of the European instruments in the collection (No. 2006) was first described by Profatius in the thirteenth century.[87] It consists of the important circles of an astrolabe plate and rete folded into a single quadrant (see Figure 28). The folded circles in this example include Tropics of Cancer and Capricorn, Equator, ecliptic and horizons for six cities (Jerusalem, Carthage, Rome, Paris, Oxford, Berwyk). In order to divide these projected circles, the curved boundary of the quadrant carries two scales. The outer one (at least on No. 2006) is characterized by equal divisions corresponding to degrees of right ascension (angular distance along the celestial equator). The unequal divisions of the inner one (again, at least on No. 2006) correspond to degrees of longitude (angular distance along the ecliptic). The radial boundaries of the quadrant also carry various scales. Astrolabe No. 2006 contains three scales: an unequally divided scale identifying the terrestrial latitude of projected horizons; an unequally divided scale identifying the celestial declination (angular distance north or south of the celestial equator) of projected parallel circles; and an equally divided scale of sines (*sinus droit*) and versed sines (*sinus versus*).

As outlined below, the sine scales are used in conjunction with the only lines comprising the quadrant, which are normally found on the back of an astrolabe, i.e., the graph of unequal hours, including the semicircle corresponding to noon. These lines appear on the quadrant as they would in the upper right quarter of a familiar European or maghribi astrolabe.

Use: The quadrant projection is useless unless it has been fitted with a thin string, fixed to its vertex and threaded with a moveable bead (No. 2006 has both). With string and bead in place, the quadrant can best be used to tell the seasonal hour from the measured solar altitude. Recall that for any day of the year the maximum (or noon) altitude of the sun is equal to 90° plus the solar declination (which may be a negative number) minus the latitude of position. Using the stretched thread, this angle is marked off along the right ascension scale (starting at the 0 hour line), and the bead is moved to the point of intersection of the thread and the sixth hour line. Leaving the bead to mark this spot, the stretched thread is moved so that it marks off the angle of

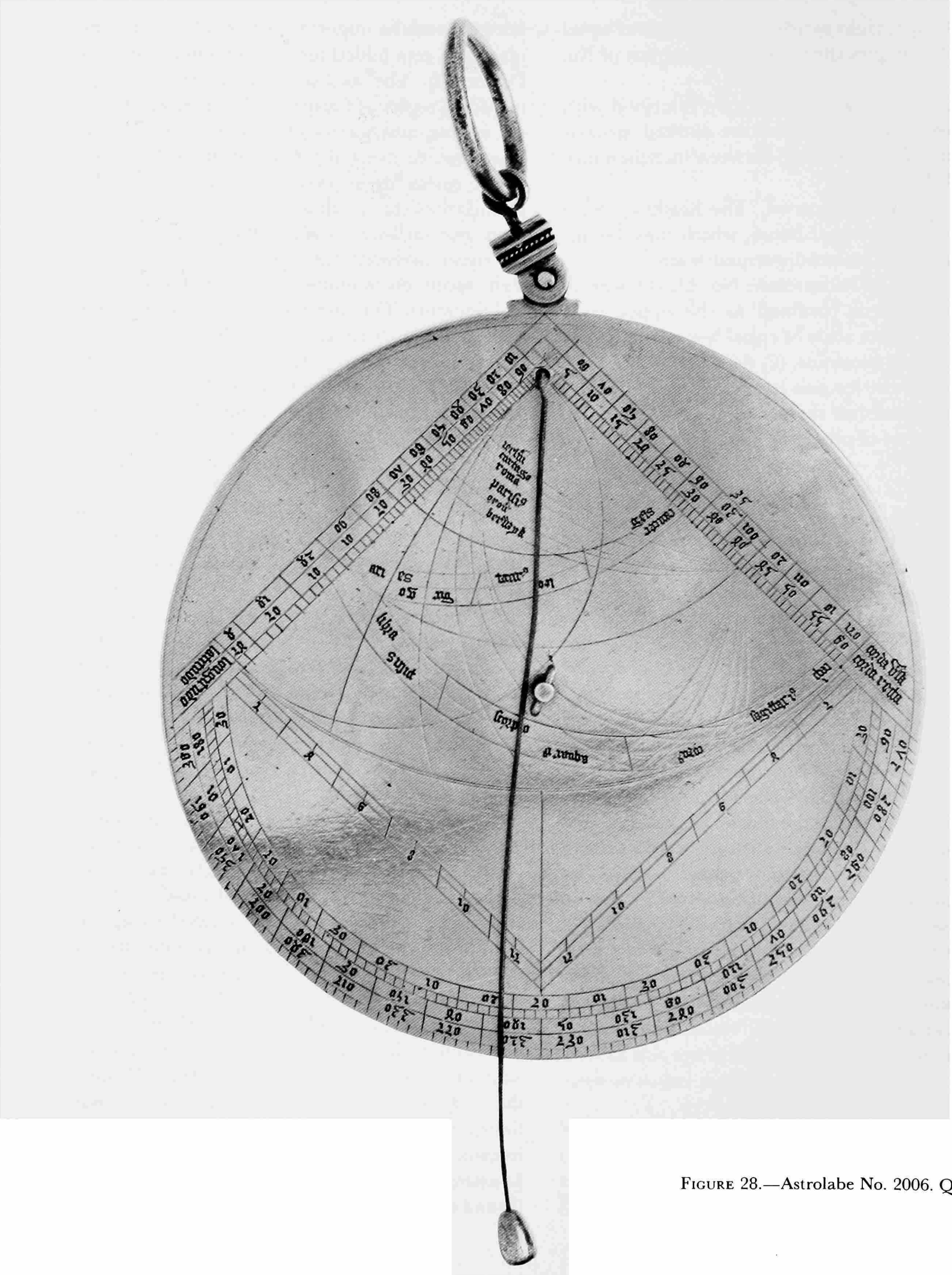


FIGURE 28.—Astrolabe No. 2006. Quadrant.

solar altitude as measured. The bead marks the appropriate seasonal hour.[88]

The declination scale can be used to measure solar declination by first moving the bead on the stretched string so that it intersects the ecliptic at the given solar longitude. Keeping the bead in place, it is only necessary to move the string to the scale and read off the declination.

De Roias Projection.—*Position and Units:* Whereas in the stereographic projection, utilized in the earliest astrolabes, the center of projection is the south celestial pole and the plane of projection is the equatorial plane, in the projection named after its originator, Johannes de Roias, celestial circles and points are projected orthogonally onto the plane of the solstitial colure. Johannes de Roias published a description of this projection in A.D. 1550.[89] It is distinguished by the straight lines parallel to the equator corresponding to parallel circles of declination and by the semi-ellipses that are the projections of meridians of right ascension. On the example in the collection (No. 2005), 37 parallels are projected (one every 5°) and 37 meridians are projected (one every 5°; see Figure 29). The parallels corresponding to the beginning of every sign of the zodiac are marked with the appropriate zodiacal symbol. The meridians are identified as hours before or after noon. In this projection the ecliptic becomes a diagonal line, passing through the center and the points of intersection of the tropics with the solstitial colure. In a major departure from the stereographic tradition, de Roias also projected bright stars on his network. The example (No. 2005) contains α Cygni, α Aquilae, α Leonis, δ Capricorni, α Canis Minoris, and α Tauri.

Use: In order to function as a nomogram, the de Roias astrolabe must be fitted with a ruler that can pivot about the center of the projection. The fiducial edge of this ruler is the projection of a horizon. Often (as the example illustrates) this ruler is divided by the orthogonal projections of azimuth circles. The ruler is completed by the addition of a small perpendicular rule, which can move freely along the ruler. This perpendicular rule, preserved in other examples, is missing from No. 2005. The rule is divided by projections corresponding to parallels of altitude.

With the complete ruler and rule in place, one can use the de Roias projection to solve all of the familiar astrolabe problems. As an example, consider the determination of the equal hour given a measurement of solar altitude.

Set the ruler so that the angular distance between it and the projection of the Earth's axis is equal to the latitude of position. Note the division on the rule corresponding to the measured solar altitude. Move the rule along the ruler so that the noted division intersects the projected parallel of solar declination corresponding to the date. The projected meridian of right ascension also intersecting at this point is the desired hour curve.

Plates

Over half of the astrolabes here considered are equipped with four (13 examples) or five (15 examples) circular plates, each plate containing projected lines on both sides. If these plate attachments are part of a proper instrument, their edges are each interrupted by a rectangular "tooth" or "notch" (see Figure 30) designed to fit into or over a notch or tooth in the raised rim of the astrolabe body. With one exception, sets of toothed plates in the collection are part of the instruments of western origin (whether European or maghribi). The exceptional set belongs to an unsigned astrolabe, which has been attributed to Faḍl ᶜAli (No. 47). Each tooth in the exceptional set is situated at the lowest point of a plate (where a notch is found on other examples originating in the mashriq) and not at the highest point, where, based on the western instruments, one would expect to find a tooth.

Contents

Colures

While other projected circles may vary from instrument to instrument, no functional plate ever lacks the basic set of projected tropics, equa-

FIGURE 29.—Astrolabe No. 2005. De Roias projection.

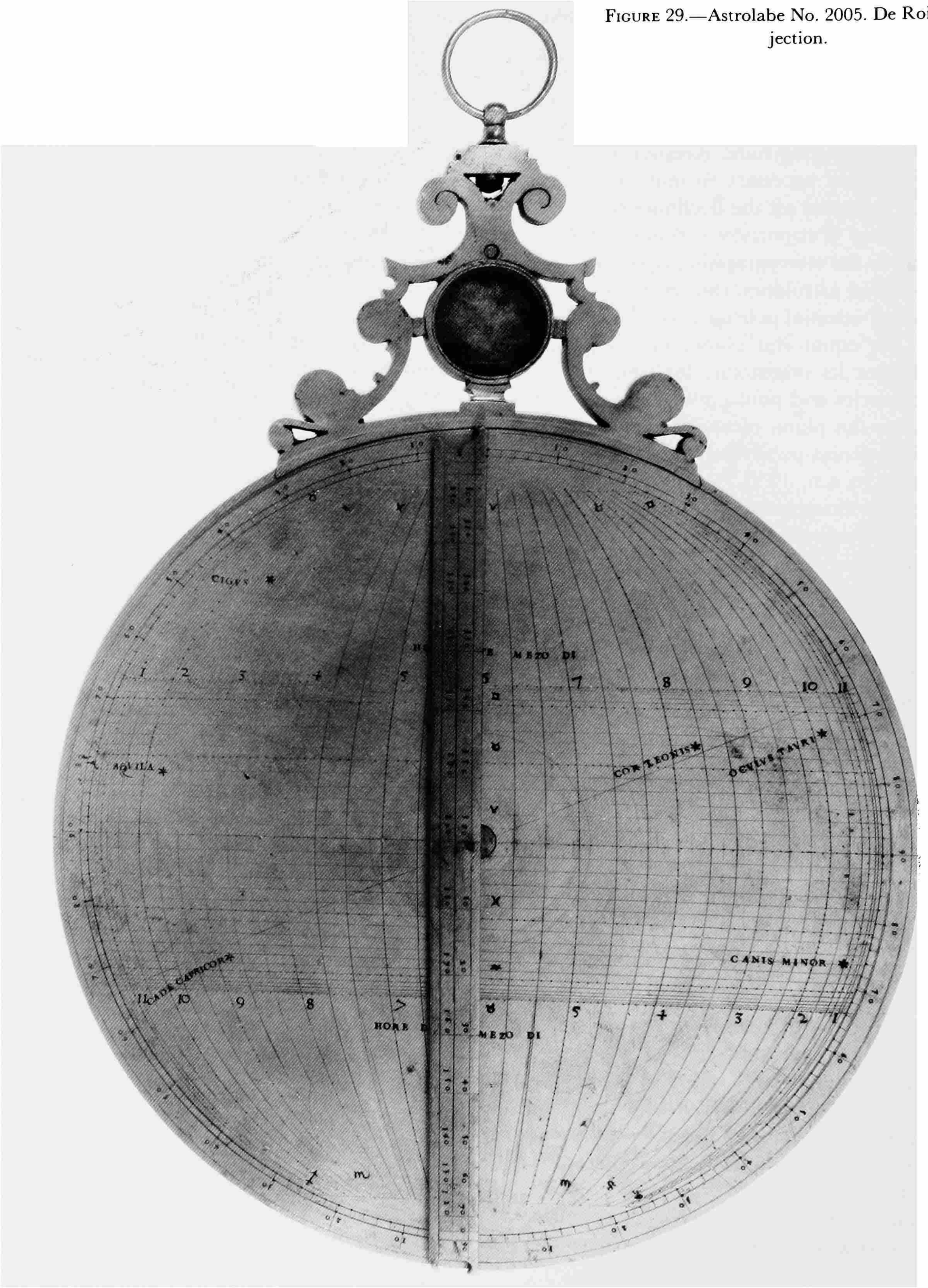
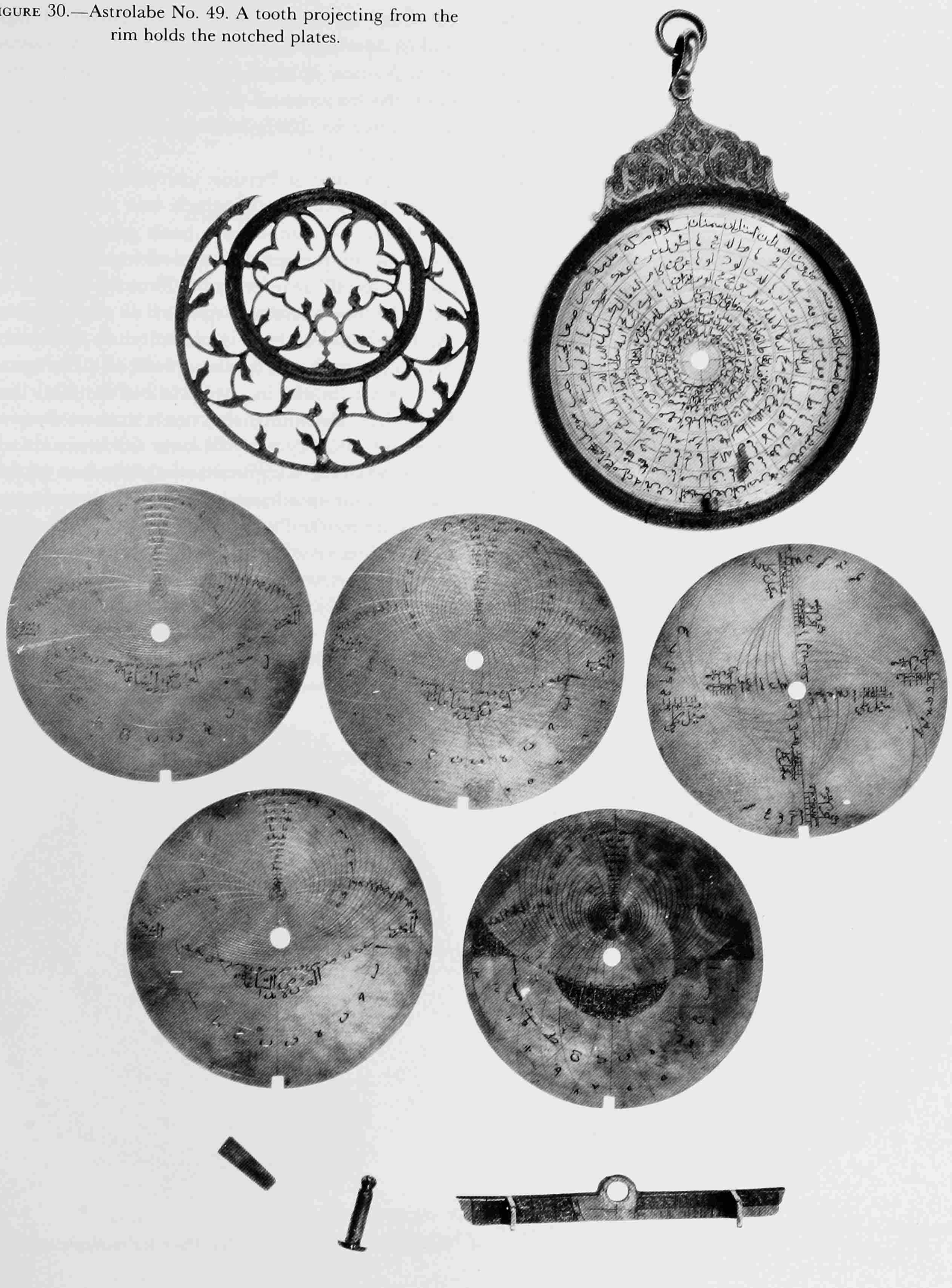


FIGURE 30.—Astrolabe No. 49. A tooth projecting from the rim holds the notched plates.



tor, and solstitial and equinoctial colures. The celestial tropics and equator are concentric circles; the colures are orthogonal straight lines. No inscription identifies the circles on Islamic instruments. On all six cataloged instruments of maghribi origin, however, the lower half of the solstitial colure is identified as *Zawāl*, *Az-Zawāl*, or *Khaṭṭ Az-Zawāl*. Inscriptions do identify the tropics and equator on two European instruments: on No. 262, *Capricornus* (outer), *Equator* (middle), and *Cancer* (inner); and on No. 2007, *Tropicus Capricorni* (outer), *Aequinoctialis* (middle), and *Tropicus Cancri* (inner). On one set of European astrolabe plates (No. 2007) the equinoctial colure is marked *Horizon Rectus* at left and right.

The Horizon Line

Aside from the stereographic projections of the solstitial and equinoctial colures (perpendicular diameters), the fundamental projected line on an astrolabe plate is the northern portion of the horizon circle for a given latitude between 23° and 64° (see Figure 31). On most instruments inscribed with Arabic characters (whether Eastern or Western) this projected line is marked with the word *Al-Maghrib* or *Maghrib* (west) at right and *Al-Mashriq* or *Mashriq* (east) at left. Analogous identification is rarer on European instruments. Only the horizons of the paper astrolabe in this collection (No. 2007) are marked *Horizon Obliquus* at left and right.

Most Arabic or Persian instruments (30 out of 41 in this collection) include one plate face on which only horizons have been projected, from four to seven per quadrant, covering the latitudes from 4° to 66° at intervals of 2° or 3°. In general, only the northeastern segment of each horizon (half its usual extent) is projected on this plate. An exception is the horizon plate of a European instrument made in A.D. 1542 (No. 221) (see Figure 32). For four instruments in the collection (Nos. 59, 61, 62, and 65) over 50 horizons are projected in eight segments of a plate face (rather than in four quadrants). Three of these instruments are marked with nineteenth century dates. In the absence of compelling contradictory evidence, it seems likely that the fourth, undated, instrument (No. 65) is also of nineteenth-century origin.

On almost half of the instruments in the collection inscribed with Arabic characters, the in-

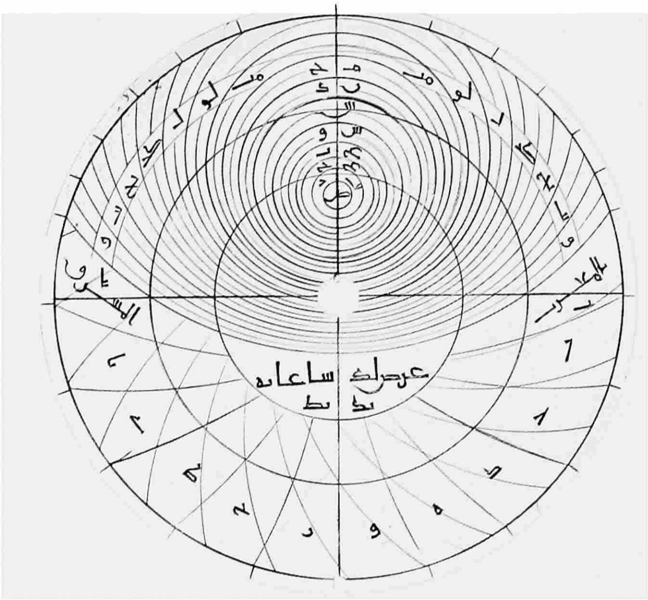


FIGURE 31.—Astrolabe No. 4. Inscription on the horizon line of the plate marks its eastern and western extension.

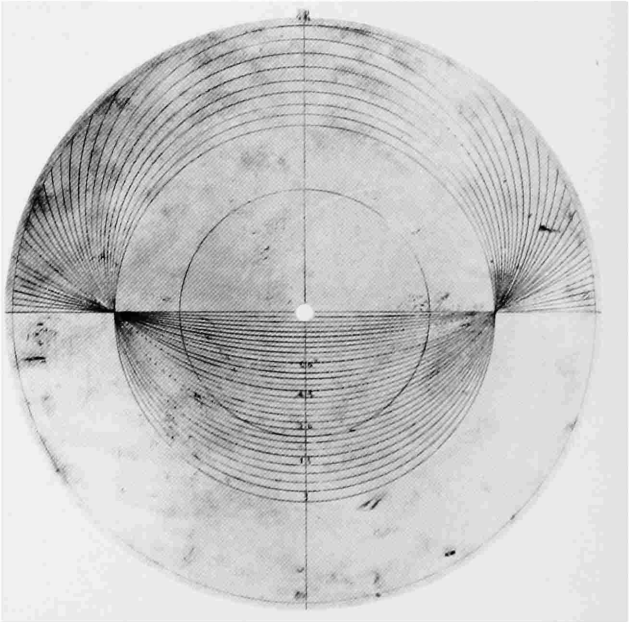


FIGURE 32.—Astrolabe No. 221. Plate for multiple latitudes.

cluded "horizon plate" also contains scales of declination along the solstitial and equinoctial colures between the tropics. Al-Biruni does not comment on the use of this scale; but no doubt it was used to mark the declination of a point on the ecliptic.

Altitudes

The number of altitudes engraved on an astrolabe plate generally depends on the plate's dimensions. In al-Biruni's words, "A complete astrolabe is one that has ninety altitudes numbered . . . 1 to 90 from horizon to zenith. If the instrument is too small to contain all these, then only every second altitude (half-size) or third, or sixth, or tenth is marked (but not fifth, although this form should be made)."[90] All but three of the instruments in this collection contain plates with altitudes projected at every 2°, 3° or 6°. Astrolabes containing altitudes at every 5° are seemingly as rare as al-Biruni indicates. Only one maghribi (No. 3643) and one European (No. 186) instrument in the collection are so engraved. The diameters of plates carrying altitudes every 3° range from 220 mm to 135 mm; diameters of plates containing altitudes every 3° range from 160 mm to 100 mm; diameters of plates containing altitudes every 6° range from 139 mm to 64 mm.

On Islamic instruments, altitudes are identified with *abdjad*[91] numbers, normally on both the left and right sides of the meridian (see Figure 33). Hindu-Arabic numerals identify the altitude on European instruments, which, if they are marked at all, are marked both at left and right of the meridian line (see Figures 34 and 98).

Twilight

The moments of nightfall and dawn are occasions for Muslim prayer, and may be indicated on the plates of instruments inscribed with Arabic characters by the stereographic projection of the lower boundary of twilight (a circle parallel to and about 18° below the horizon). Only one Arabic instrument in the collection (No. 52) includes such a twilight line (engraved *shafaq al-fajr*) on its plates. However, plates on three European astrolabes (Nos. 262, 2005, and 2007) carry the

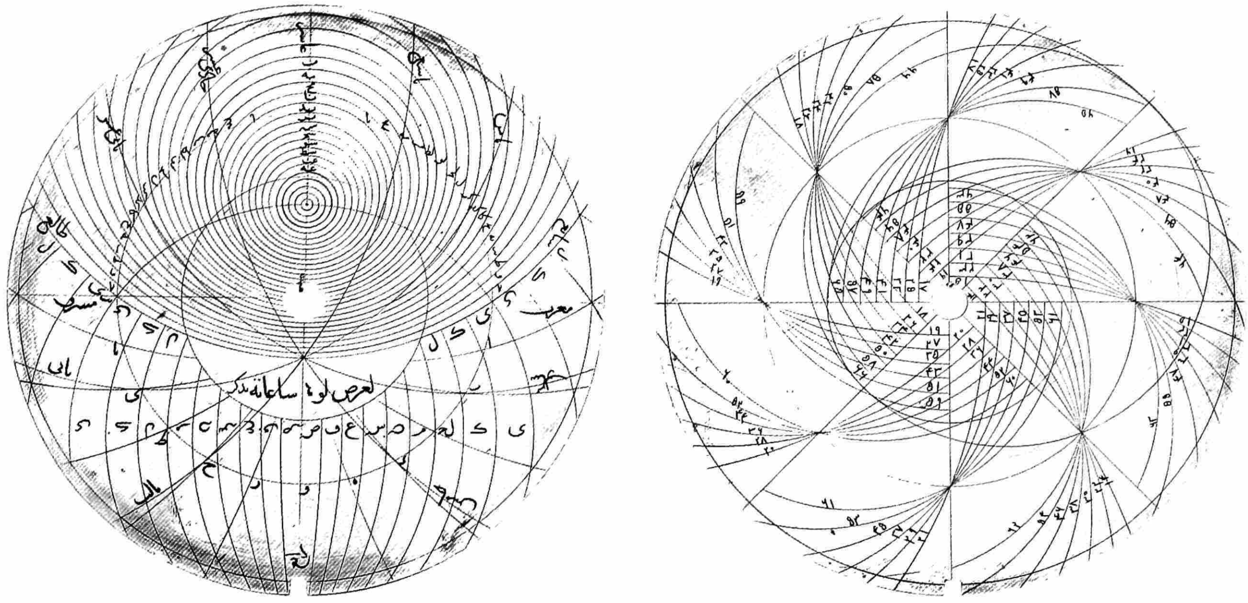


FIGURE 33.—Astrolabe No. 65. Plates for 36° latitude (left) and multiple latitudes (right). Compare with Figures 32 and 34.

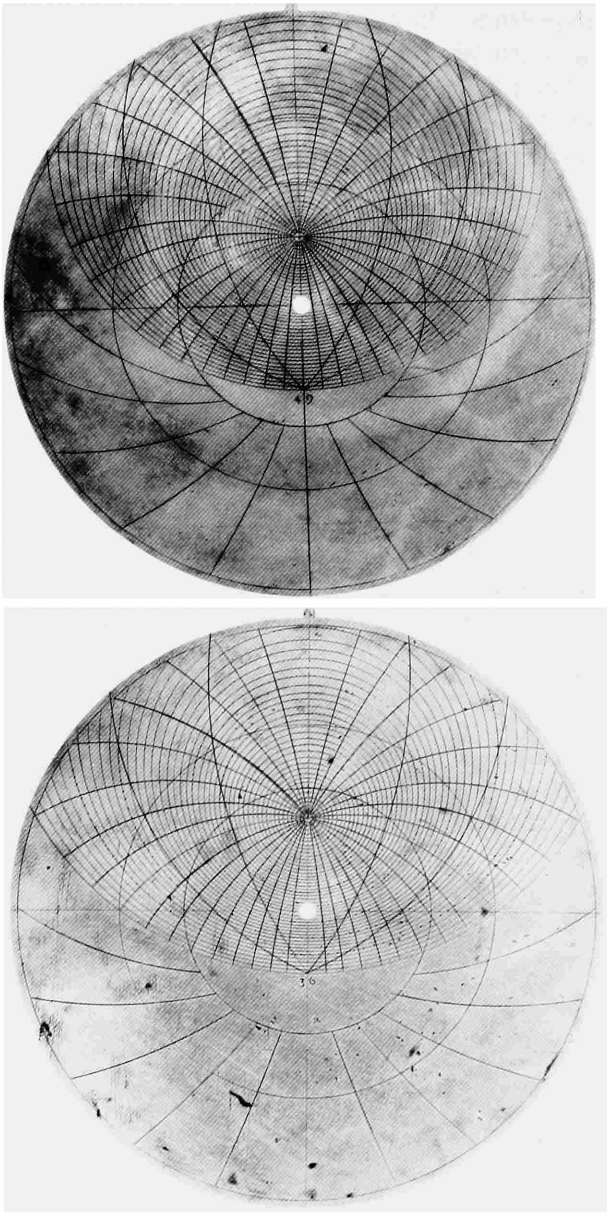


FIGURE 34.—Astrolabe No. 221. Plates for 49° (top) and 36° (bottom). Compare the lower plate with the plate for 36° in Figure 33.

twilight projection. In one case (No. 2007), the projection is marked *Linea Aurorae sive crepusculinae.*

Azimuths

Projections of azimuths, or great circles passing through zenith and nadir points, are found on the plates of all but two of the astrolabes in the collection. These are distributed, in the overwhelming majority of cases, at intervals of 10°. The few exceptions contain azimuths projected at 5° (Nos. 25, 64, 187, 2007, and 2566), 6° (Nos. 2569 and 3643), or 15° (Nos. 85, 304, 4000) intervals. *Abdjad* numbers identify azimuth lines on instruments inscribed in Arabic characters; Hindu-Arabic numerals, on European instruments. In every case the numbering begins at the intersection of prime vertical and horizon and continues to 90° at the intersection of solstitial colure and horizon.

A set of astrolabe plates commonly includes a projection for latitude 66° (see Figure 35). The practice appears to be limited to instruments inscribed with Arabic characters (at least in this collection). That this face served to verify the celestial latitude and longitude of stars included in the ^{c}*ankabūt* is suggested by its typical identifying inscription: *(ṣafīḥa) mīzān al-*^{c}*ankabūt* (Nos. 85, 86, 87 and 2569). The content of this face is generally limited to altitudes and azimuths (with major divisions identified by names of zodiacal signs). The inclusion of an ^{c}*ankabut* plate apparently is not confined to a single Islamic maker or locale. The instruments in the collection associated with ^{c}Abd al-A$^{\circ}$imma suggest that some makers preferred not to include a rete projection.

Azimuth lines projected onto an astrolabe face generally occupy the area above the projected oblique horizon; but, as examples in this collection illustrate, some makers preferred to project only the portion below the horizon on some plates (see Nos. 15, 44, 57, 65, and 86). Some astrolabists projected all the azimuths that fit between the projected zenith and Tropic of Capricorn (see Nos. 47, 59, and 62). On many examples of plates, the prime vertical alone was projected above and below the horizon (Nos. 61, 66, 85, and 2569).

Unequal Hours

On the plates of all but one astrolabe in the collection, the projections of tropic and equator circles below the horizon are divided into 12 equal parts by the so-called "seasonal" hour lines.

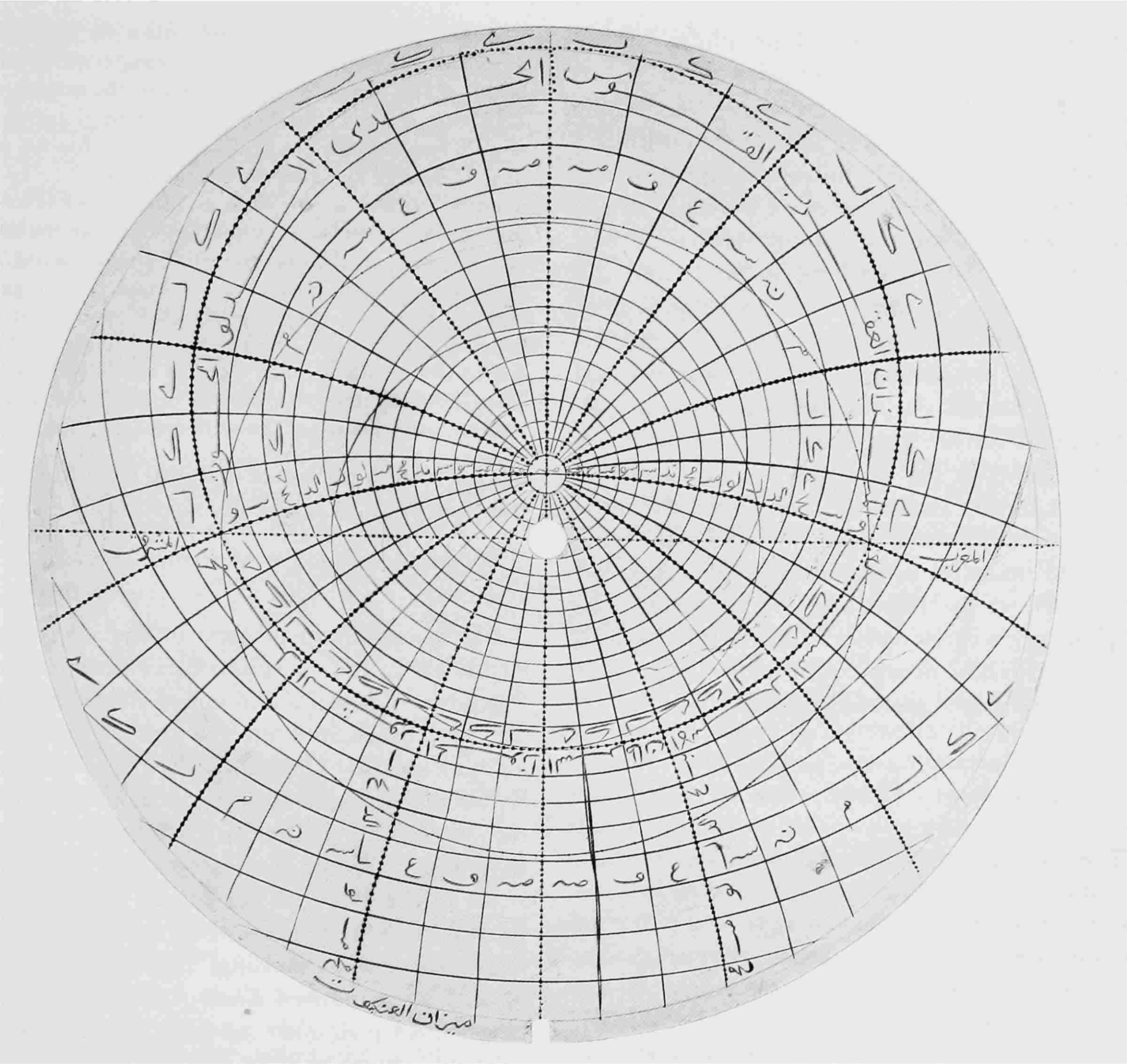


FIGURE 35.—Astrolabe No. 88. Plate for 66° latitude, used to verify celestial latitude and longitude of stars on the ^{c}*ankabūt*.

The set of plates without seasonal hour lines belongs to an instrument of questionable functionality inscribed with Arabic characters (No. 2570). On European instruments, the unequal hours are generally marked by Hindu-Arabic numerals. On instruments in the collection inscribed with Naskhi characters, *abdjad* numbers mark the unequal hours; on two Naskhi examples (Nos. 25 and 40) these numbers are replaced by the ordinals from "first" to "twelfth": *Al-Awwal, Ath-Thānī, Ath-Thālith, Ar-Rābi*^{c}, *Al-Khāmis, As-Sādis, As-Sābi*^{c}, *Ath-Thāmin, At-Tāsi*^{c}, *Al-*^{c}*Ashir, Al-Ḥādī, Ath-Thānī* ^{c}*Ashar*. The latter convention is more typical on maghribi instruments (specifically, four out of six in the collection).

Astrolabe No. 2572 incorporates seasonal hours, which are identified according to astrological practice as being either male or female, and either animal, vegetable, or mineral (see p. 175).

Equal Hours

Astrolabes in the collection that are of European or maghribi origin do not carry plates engraved with hours other than seasonal. Other

types of hours are projected on plates of the collection's instruments originating in the mashriq, in all but three cases. These supplementary hours are 1/24 of a day and are of equal duration throughout the year. In most examples in the collection they are counted from the western horizon (*horae ab occasu* or Italian hours); in one example, No. 2566, they are counted from the eastern horizon (*horae ab ortu*, or Babylonian hours); and in four examples (Nos. 54, 58, 87, and 88) they are counted from both eastern and western horizons. As Hartner[92] points out, an explanation for the preference for *horae ab occasu* can be found in the fact that the Muslim day begins at sunset. Except in cases where the same numbers identify both equal and unequal hours, the equal hours on instruments in the collection are identified by Hindu-Arabic numerals. On only one plate carrying hours counted from both horizons are those hours identified (No. 58); other double projections are uninscribed.

Houses

The astrological houses, a division of the ecliptic into six parts above and six parts below the horizon, are rarely projected onto the plates of instruments inscribed with Arabic characters. No. 65 is the only one mashriqi instrument in the collection with such a projection (see Figure 33). On the other hand, four western instruments (Nos. 204, 221, 2005, 2007) include plates with house divisions. On the astrolabe from the mashriq, the houses are marked with the ordinals (starting at the eastern horizon and proceeding counterclockwise): *Ṭāliᶜ*, *Thānī*, *Thālith*, *Rābiᶜ*, *Khāmis*, *Sādis*, *Sābiᶜ*, *Thāmin*, *Tāsiᶜ*, *ᶜĀshir*, *Ḥādī ᶜAshar*, and *Thānī ᶜAshar.* The houses on the European instruments are marked either with Roman numerals (Nos. 204, 2005) or with Hindu-Arabic numerals (Nos. 221, 2007).

The fact that houses are not normally engraved on instruments inscribed with Arabic characters is perhaps explained by the accepted Muslim procedure for determining house divisions as described by al-Biruni (using the rete and appropriate plate):

> To equalize the twelve houses, place the degree of the ascendant [the point of the ecliptic rising at the moment of birth] on the east horizon, the point of the ecliptic on the west horizon is the cusp [beginning boundary point] of the seventh house. Then look at the meridian, what has arrived there is the sign and cusp of the tenth house . . . . To determine the cusps of the other houses, turn the rete inversely so that the degree of the ascendant comes under the horizon, and is placed on the line indicating the beginning of the eleventh unequal hour, i.e., through two temporal hours . . . then look at the meridian line to see what sign is there and what degree; it will be the cusp of the ninth house and its degree, the nadir of which is the cusp of the third. Then move the rete . . . so that the degree of the ascendant rests on the beginning of the ninth hour.[93]

Such a systematic use of unequal hour lines makes the projection of house divisions unnecessary.

Prayers

Plates contained in each of the maghribi instruments in the collection carry lines that mark four times of Muslim daily prayer. Although these are day times, the lines seldom interrupt the altitude circles. Generally they are distributed between the projected unequal hours, within the second, eighth, tenth, and eleventh. Placed as they are, it is thus the intersection of the nadir point of the sun with these lines that marks the prayer times in the morning, at midday, in the afternoon, and at evening. The lines (from right to left) are inscribed *Khaṭṭ Ash-Shafaq* (morning prayer), *Khaṭṭ Aẓ-Ẓuhr* (midday prayer), *Khaṭṭ Al-ᶜAṣr* (afternoon prayer), and *Khaṭṭ Al-Fajr* (evening prayer). In the light of the evidence presented by the collection, it seems that Hartner's statement[94] that "most Islamic astrolabes" have prayer lines should be revised to refer to "most maghribi astrolabes."

Latitude and Length of Daylight

The differences between networks of lines projected on the faces of a set of astrolabe plates are important, to be sure, but subtle enough to require distinguishing inscriptions. On every functional plate face, an inscription somewhere along the meridian, below the horizon, identifies the latitude for which the projection applies. On most instruments inscribed with Arabic characters this

inscribed latitude (ᶜ*Arḍ*) is accompanied by an associated length of daylight (*sāᶜātuhu*). These associations of latitude with length of daylight were presumably taken from tables that had been a part of the geographic literature since Ptolemy. Two distinguishable methods are represented by astrolabes in the collection (see Table 15). The first (A) is represented by a majority of the examples, including the four instruments signed by ᶜAbd al-Aʾimma. It is based on the assumption that the obliquity of the ecliptic is 23.59°. The second (B) follows the convention of incrementing the length of daylight by four minutes of time for every increase of a degree of latitude. One very early (No. 4) and two relatively late (Nos. 52, 53) astrolabes in the collection follow the latter.

Most Eastern instruments contain plates only for integral degrees of latitude. One exception (No. 88) has a plate face for latitude 21°40′ (= Mecca) and a plate face for 31°50′ (= Lahore). A second exception (No. 42) has a plate face for 29°26′ (≃ Shiraz 29°36′) and a plate face for 32°20′ (≃ Iṣfahan 32°35′). Both No. 37 and No. 64 have plate faces marked 38°05′, corresponding most closely to the latitude of two towns on the gazetteers of these instruments: Tabriz (38°00′) and Ardabil (38°00′). No. 64 also has a plate face marked latitude 42°08′; there is no equivalent latitude on its gazetteer.

TABLE 15.—Length of daylight associated with latitude via two distinct traditions

Latitude (°N)	Length of daylight			
	Tradition A		Tradition B	
	Hours	Minutes	Hours	Minutes
30	13	57	14	
31				
32	14	7	14	8
33				
34	14	17	14	16
35				
36	14	28	14	24
37				
38	14	39	14	32
39				
40	14	52	14	40

Latitudes engraved on maghribi and European instruments are not generally associated with lengths of daylight. Maghribi instruments in the collection tend to include plate faces for latitudes 21°40′ (or 21°30′), 31°30′, and 33°40′ (or 33°30′). Plate faces on the European instruments in the collection are limited to integral degrees except for the plate engraved 43°30′ (= southern France?) on No. 221.

ENGRAVING STYLE

The networks projected onto an astrolabe plate face are generally made of continuous engraved lines, blackened for emphasis. Notched, dotted, or jagged lines may appear on maghribi instruments (see Nos. 186, 2571, 3643, 4001). The latter technique is used to emphasize prayer lines, prime vertical, and certain altitudes (the third, fifth [or sixth], tenth, or twentieth). Dotted lines are occasionally incorporated into the networks engraved on plates of European instruments (see Nos. 221 and 262). These emphasize every fifth altitude or (in one case) the equal hours. The unequal hours on plates belonging to instruments made in the mashriq are often marked with dotted lines (Nos. 4, 15, 55, 57, 58, 59, 62, 64, 85, 86, 2566, 2569, 3811, and 4000), very likely to distinguish them from seasonal hours also projected below the horizon. On some plates of Eastern origin, dotted lines also distinguish some azimuths (at least the prime vertical) and altitudes (including the oblique horizon). On the basis of the evidence in the collection, it is not possible to attribute the use of dotted lines to any motivation other than the whim of the maker. None of the instruments made or decorated by ᶜAbd al-Aʾimma incorporate dotted or otherwise interrupted lines.

Rete

As instruments in the collection illustrate, functional astrolabe retes invariably incorporate a stereographic projection of the ecliptic circle. This element of the design is usually defined by the beveled outer edge of a circular band attached

by thin struts to a flat ring surrounding the projection of the celestial poles. The beveled edge of the ecliptic band is most often divided into degrees; the band itself usually is divided into 36 subdivisions of 10° of the 12 zodiacal signs. On astrolabes made in Europe and the mashriq, the zodiacal signs are invariably identified by name; the familiar symbols appear on some maghribi examples. Numerals identify each subdivision as being 10°, 20°, or 30° of a sign.

When a properly divided ecliptic circle is rotated about the projection of the celestial poles, the degree of celestial longitude corresponding to solar position on any given day traces the apparent path of the sun. The implications of this fact become apparent when the uses of the astrolabe are detailed.

Instructions for properly dividing the stereographically projected ecliptic circle are supplied perhaps for the first time, in Ptolemy's essay on the planisphaerium.[95] Ptolemy uses radii corresponding to the right ascension of the end points of each zodiacal division to achieve his goal. Emmanuel Poulle describes five other popular division methods, each with its own history in the literature[96] (see Appendix III).

On every astrolabe inscribed with Arabic characters and on two European astrolabes (Nos. 186 and 204) there is a projection on the ecliptic (called a *murī* in Arabic) at the beginning of Capricorn (see Figure 9). It is used to indicate positions on the rim scale when the rete is rotated.

The bands that attach the ecliptic circle to the ring around the projection of the celestial pole generally follow the projection of the equinoctial colure. The best makers incorporated counterchanges into these bands so that the exact position of the projection of the equinoctial colure could be seen readily. A lack of equinoctial colure bands may, but need not, identify a non-functional rete. Certainly four suspect retes in the collection (Nos. 49, 64, 66, and 86), all of which lack these bands, support this suggestion. On the other hand, curving vines without equinoctial colure bands connect the ecliptic to the celestial poles on two well-made retes from the mashriq (Nos. 54 and 55), both dating from the eighteenth century. One could conclude on the basis of examples here studied that only very good or very bad rete makers eliminated the connecting equinoctial colure bands.

The astrolabe as a timekeeper is distinguished from its near relative, the sundial, by the fact that its usefulness can be extended beyond sunset. This advantage is achieved through the incorporation of the stereographic projections of selected stars into the rete design. As these projected stars rotate about the projection of the celestial pole, they duplicate the apparent motion of their counterparts in the heavens. If they are sufficiently well distributed, the projected stars can thus serve as adequate markers of the passage of night time.

Rete makers positioned star pointers using coordinates supplied by tables of fixed stars. The Arab astronomer aṣ-Ṣufi (A.D. 903–936) effectively published such a list when he designated 37 stars in his "Treatise on the Fixed Stars" (A.D. 964) as "astrolabe stars." European works on the construction and use of the astrolabe tend to include a *tabula stellarum fixarum.*[97] Most of these *tabulae* give the name of the star, the *coeli mediationem* (or the point on the ecliptic having the same right ascension as the named star), and the declination of the star. All editions of Johannes Stöffler's *Elucidatio Fabrica* include, besides the typical table of mediations and declinations, a table of stars along with their celestial latitude and longitude. A maker could plot these latter stars using the same procedure he employed in engraving an astrolabe plate for latitude 66°. Poulle[98] describes how makers utilized various parameters (including latitude and longitude) to position stars.

The list of stars projected onto the retes of most instruments (over 30 mashriqi and maghribi) in the collection would have to include (1) α Tauri, (2) β Orionis, (3) α Orionis, (4) α Canis Majoris, (5) α Canis Minoris, (6) α Hydrae, (7) α Virginis, (8) α Bootes, (9) α Corona Borealis, (10) α Ophiuchi, (11) α Lyrae, (12) α Aquilae, and (13) α Cygni (see Figure 9). The first seven of these "most popular" stars lie south of (outside) the ecliptic between Aries and Libra, the last six lie north of (inside) the ecliptic between Libra and Pisces. All of the "popular" stars are included in

al-Ṣufi's list. About 36 other recognizable stars appear with varying frequency on retes in the collection (see Appendix II). No obvious single quality characterizes all of them. Most are either quite bright or are located in well-defined positions within a constellation figure (at the corners of a box, at the vertices of a triangle, at the beginning or end of a line).

The point projections of stars appear on each rete as the tips of leaves or flames or daggers. Since none of these could spring from the outer edge of the ecliptic band without detracting from its usefulness as a timekeeper, additional supporting strapwork had to be included in each rete design. Every rete in the collection contains an almost complete Capricorn circle in the supporting strapwork. This circle is tied to the ecliptic circle by projected equinoctial colure bands (usually counterchanged) and, generally, also by thin curved ties near Pisces 0° and Scorpio 0°. No other elements of rete strapwork are common to all examples in the collection.

Inside the Capricorn circle, the pattern of supporting strapwork forming an astrolabe rete tends to identify its maker (see, for example, Nos. 40, 37, and 39). Certain components of the generally individualistic designs are, however, shared by more than one maker. In a majority of examples, makers have incorporated some portion of the stereographic projection of the celestial equator into the pattern of rete strapwork. A second strapwork component shared by a majority of examples is some portion of the stereographic projection of the solstitial colure or meridian circle. Retes that do not include either of these elements generally consist of arabesque or baroque openwork, or of combinations of non-astronomical circular arcs.

On the back of some astrolabe retes, there can be seen the remains of engraved lines and circles. These undoubtedly evidence steps in the construction process. The guidelines usually consist of stereographically projected colures, tropics, and equinox. Occasionally the remains of a divided ecliptic may be detected (see, e.g., No. 62 in Figure 36).

The astrolabe rete is used in combination with one of the plates to represent a given configuration of the heavens with respect to the horizon. The representation may in turn be interpreted as an indication of the time of day or night or as an indication of an individual's horoscope.

According to Mashaʾallah:

If you wish to know the hour at night, take the altitude of any star marked on the *alhanthabuth* [rete] . . . ; place the *cacumen* [tip of the star pointer] of the star on . . . its altitude [on the plate], and the degree of the sun [on the ecliptic] will show you the hour of the night.[99]

According to al-Biruni:

To determine the ascendant from [a measured solar] altitude, select the disc [plate] constructed for the place of observation (or as nearly as possible), place it uppermost, and fit the rete over it. Then find and mark the *muqantara* [projected altitude circle] which has the same number (or nearly the same number) as the [measured solar] altitude. Thereafter ascertain from a [zodiacal] calendar the exact place [longitude] of the sun at that time, and mark that point on the corresponding sign of the zodiac [ecliptic] on the rete. Then rotate the rete until the degree in question is over the *muqantara* already marked, and note what sign and what degree thereof coincides with the eastern horizon. This is the ascendant.[100]

Accessories

Alidade Scales

Position: The scales extend along the left arm with beveled edge at top and along the right arm with beveled edge at top (see Figure 8).

Units: The only divisions on the left arm generally correspond to the major divisions of the declination scale engraved on the back of the astrolabe; i.e., the arcs representing solar declination at the time it enters each zodiacal sign, inscribed with names of zodiacal signs (left arm at bottom in Figure 8). The beveled edge of the right arm normally contains a length equal to and coterminal with the radius of the upper left quadrant on the back of the astrolabe. This length is divided into 60 equal parts, with every fifth division extending onto the upper half of the flat surface of the alidade and inscribed with a numeral (Figure 8). The lower half of the right arm of the alidade in most cases contains five unequal divisions extending from the right sighting plate

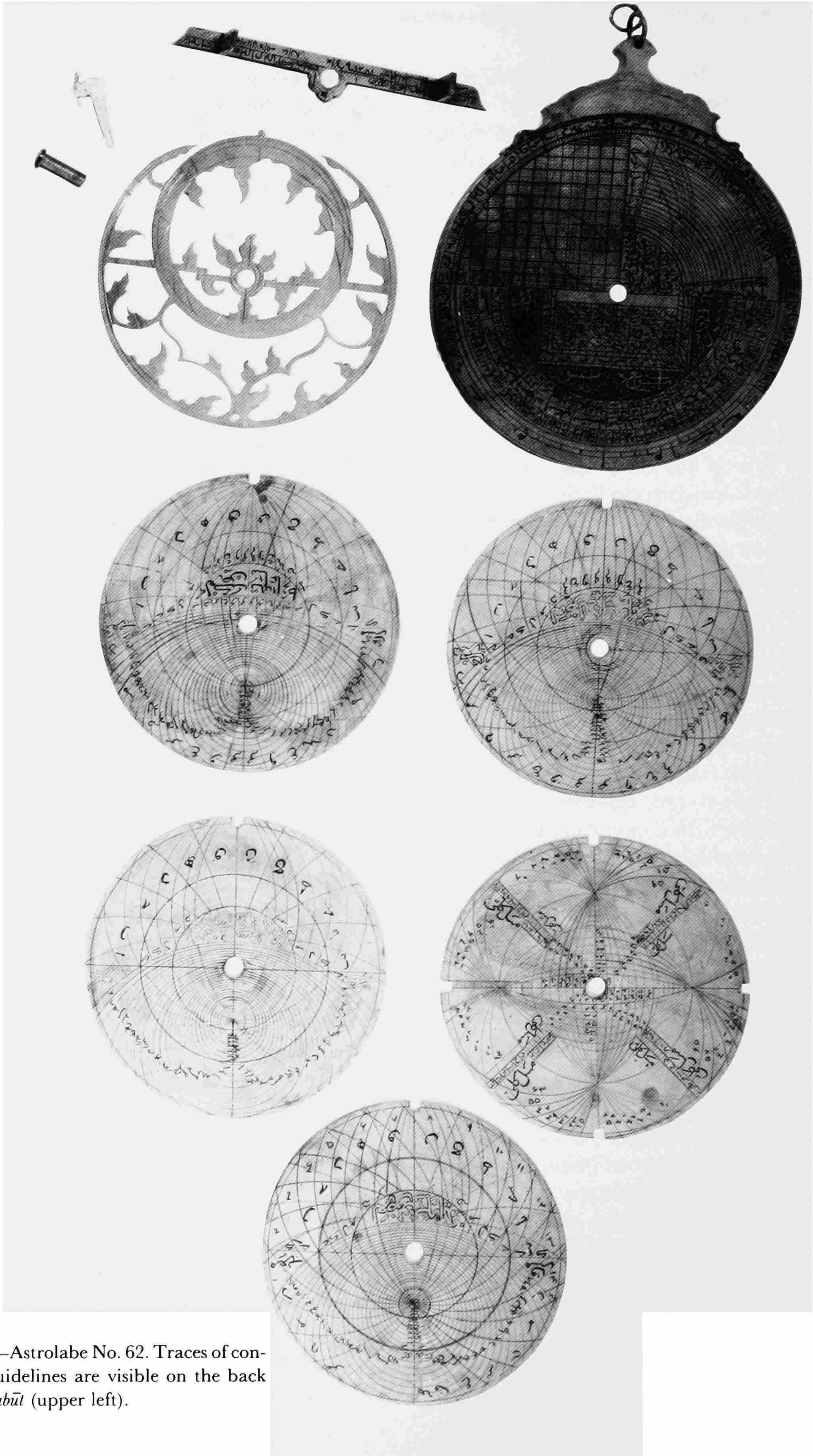


FIGURE 36.—Astrolabe No. 62. Traces of construction guidelines are visible on the back of the ᶜ*ankabūt* (upper left).

to the center and corresponding to the length of the shadow of the sighting plate as it falls on the alidade at the seasonal hours of the day, inscribed with numerals (Figure 8).

Use: The left arm of the alidade essentially functions as a moveable equivalent of the names of zodiacal signs inscribed along the 0° radius of the astrolabe back. The inscription identifies the declination arcs upon which prayer lines and Qibla azimuths are engraved. By repeating these identifiers on the alidade, the astrolabist has made easier the interpretation of the lines engraved in the area between the 0° radius and the 45° radius. The equally divided scale along the upper right arm of the alidade can be used to measure sine lengths along the 90° radius of the back of the astrolabe (and cosine lengths along the 180° radius). For that matter, the scale can be used to measure the distance along any quadrant radius.

The scale of unequal divisions engraved on the lower right arm represents a time-keeping technique known from Graeco-Roman antiquity. The presence of such a scale identifies the astrolabe as a portable sundial, equivalent in design and utility to five ancient portable dials found near Bratislava, near Crêt-Chatelard, at Rome, Memphis, and Aphrodisias.[101] In order for the dial to mark the seasonal hours for any day at any given latitude of position, the alidade must be suspended so that it lies in the meridian plane, so that it is inclined to the vertical by an angle equal to the altitude of the noon sun at the given latitude on the day in question, and so that the shadow of the right sighting plate falls on the sundial scale. The second contingency can easily be satisfied by making use of the plates of the astrolabe (see page 56). If there is no plate for a given latitude, the dial can still be used to approximate the seasonal hours by setting the alidade so it is inclined to the vertical at an angle equal to the latitude.

According to Mashaᵓallah:

If you wish to know the natural [seasonal] hour of the day by the horary alidade, set the alidade on the [sun's] altitude at midday on the back of the astrolabe suspended, turn the back to the sun until the shadow of each corner of the upper pinnule falls on the alidade anywhere in line with its side. Then the division on which it falls will be the desired hour.[102]

Remarks: Without exception, the alidades on European astrolabes in the collection are counterchanged about the center. Only one astrolabe of non-European origin in the collection (No. 55) has a counterchanged alidade. All other non-European alidades in the collection are not counterchanged.

The scales described above appear on the alidades of about half the non-European astrolabes in the collection. The remaining non-European alidades in the collection are uninscribed. None of the scales described above appear on European astrolabes in the collection. Five of these European alidades are blank. One (No. 2007) is inscribed with a maker's name. On one (No. 204) the words *Linea Fiducie* and *Alhidada* have been inscribed. The alidade accompanying the astrolabe incorporating a de Roias projection (No. 2005) has been inscribed with two scales: one is a scale of equal divisions to be used with a plate to convert equal to unequal hours; the other represents the stereographic projection of the 5° and 10° points between the equator and the North Pole of a sphere of radius equal to the radius of the Capricorn circle on the plate.

Index Scales

Position: The scales extend along the beveled edge.

Units: These scales are marked at twelfths of the radius of the front central area (numbered), or 5° (unnumbered) and 10° (numbered) units of declination (No. 262).

Use: See the section on "Alidade Scales," the discussion of the upper right arm (see above). The divisions of this scale coincide with stereographically projected parallels of declination. Thus, the scale may be used to measure the declination of the sun or any star on the astrolabe rete. Blank index arms may conveniently be used in combination with rim scales to determine the equal hour.

Remarks: Only nine astrolabes in the collection are equipped with an index arm. Four of

these are radial. Five are complete. The index arms on five astrolabes (Nos. 31, 186, 221, 304, and 2007) are blank. The complete index arm on a non-European astrolabe made in A.D. 1783 (No. 55) carries no scale but is decorated with vines and flowers on a stippled background. The complete index arm on the European astrolabe signed "I. Galois" (No. 204) carries no scale but is inscribed *Linea Fiducie* on each arm. The scale (see above) on the radial index arm of the Hartman astrolabe (No. 262) is identified with the inscription, *Lati : Meridio : Latitvdo Septrionalis.* The scale on the complete index arm of the astrolabe signed Ṣadiq (No. 52) is untitled.

Catalog of the Collection

Each of the 52 astrolabes described in the following catalog is identified by the number assigned to it in *A Computerized Checklist of Astrolabes* compiled by Sharon Gibbs, Janice Henderson, and Derek Price and published by the Department of History of Science and Medicine at Yale University in New Haven, Connecticut, in 1973. The *Checklist* is referenced in the catalog as CCA. The numbers assigned by Gibbs, Henderson, and Price preserve numbers assigned to almost 400 astrolabes by R.T. Gunther (1932) in his *Astrolabes of the World.* These numbers are correlated with Catalog Numbers of the National Museum of American History and the S.V. Hoffman collection in Table 16.

The date given for each astrolabe, unless it is preceded by the qualifier "ca.," is exactly what appears inscribed on the instrument. When the inscribed date refers to a calendar other than the Julian or Gregorian (e.g., the Hegiral calendar), it is followed by brackets enclosing the Julian or Gregorian equivalent. Signed but undated astrolabes have been assigned to the middle of the maker's productive period. In the absence of any inscriptions, the astrolabe's date has been estimated from the celestial longitudes of the stars in its rete or from the date of the vernal equinox indicated on its calendar scale. The "Signature" section has been reserved for the name of the maker or decorator.

Translations of inscriptions that were contributed by George Saliba have been identified with the symbol "GS." The catalog entries include mention of all inscription occurring on each astrolabe. The names of cities and geographic parameters inscribed in the front body of an astrolabe are reported in tabular form in Appendix I. Similarly, star names appearing on an astrolabe star map or rete are tabulated in Appendix II.

Unless otherwise indicated, the reader may assume that there are no engraved details or other original marks on the edge of the astrolabe. The two sides of a given astrolabe plate have been designated side "a" and side "b" (e.g., 6a and 6b).

All of the astrolabes described in this catalog, including those no longer in the National Museum of American History (CCA Nos. 4, 42, 55, 58, 65, 88, and 144), have been examined by the author.

TABLE 16.—Cross references to numbers identifying astrolabes (CCA = number assigned in *A Computerized Checklist of Astrolabes*, Gibbs, Henderson and Price [1973]; NMAH = catalog number assigned by the National Museum of American History; H = Number assigned by Samuel Verplanck Hoffman)

CCA	NMAH	H	CCA	NMAH	H
4	322458	28	86	316754	29
15	336113	13	87	336115	19
25	336112	12	88	322464	5
31	316767	39	144	322463	2
37	333589	20	186	316757	33J
39	336114	16	204	316760	35
40	316761	18	221	316759	34
42	322460	37	262	336117	33
44	316763	26	304	316758	36
47	316764	6	2005	316756	40
49	333586	8	2006	318198	
52	316765	24	2007	322083	
53	316766	27	2566	333588	15
54	333590	30	2567	316770	17
55	322461	31	2568	316751	41
57	333587	10	2569	94624+A	
58	322459	11	2570	315064	
59	336090	14	2571	316752	
61	316768	7	2572	318178	
62	316769	22	3643	316753	1
63	215454.34	25	3811	215454.33	9
64	336116	23	4000	330778	
65	322327	32	4001	330779	
66	316762	21	4002	333932	
70	316755	4	4003	333933	
85	316750	38	4004	79.852.01	

FIGURE 37.—Astrolabe No. 4. Front view.

CCA No. 4

FIGURES 31, 37, 38

Date: A.H. 547 [1152].

Signature: Ḥamid ben Maḥmud al-Iṣfahani.

Components: Body with throne (rim with throne riveted to backplate with throne), handle, ring, three plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 134 mm.

Material: Brass.

Characteristics: The pierced throne is a Moorish arch formed by intertwining vines. The handle is ring-shaped. The ring itself has no visible join. Two concentric circular scales divide the rim into 1° and 5° intervals. Inscription on the latter identifies it as a 360° scale. The first subdivision is marked with an *abdjad* "5;" the last, "60." Eight concentric bands engraved in the front central area suggest that a gazetteer was planned, but never completed. The back margin is divided into altitude scales in the upper sections and a cotangent scale in the lower right section. The lower left margin has been reserved for the maker's signature. The two upper quadrants contain a set of six equally spaced declination arcs crossed by four prayer lines, two (*khaṭṭ awwal waqt aẓ-ẓuhr* and *khaṭṭ awwal waqt al-ᶜaṣr*) each for latitudes 36° and 32°25′ (?Iṣfahan). The two lower quadrants contain five semicircular astrological scales: zodiacal signs, planetary governors of terms, terms, planetary governors of faces, and face degrees. Five symbols identify the planetary governors of the terms: a Roman Z with horizontal slash is Jupiter, a vertical arrow with a ball at its tip is Venus; a vertical line topped by a ball topped by a Roman U is Mercury; a vertical arrow intersecting a ball is Mars; an unmodified Roman Z is Saturn.

Three notched plates fit into the recessed area in the front of the astrolabe. Of the six plate faces, only one (3a) carries the complete standard network (of colures, equator, tropics, horizon, altitudes, azimuths, and seasonal hours) and it is supplemented by a projection of equal Italian hours and a projection of Muslim prayer lines. No azimuth lines are included in the networks of four of the remaining plate faces; two faces that lack azimuth lines do have lines for the equal Italian hours. Altitudes have been projected at 3° intervals. The identifying inscription on each face specifies latitude and length of daylight as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ᶜarḍ* 31	*sāᶜātuhu* 14 03
2a	*ᶜarḍ* 30	*sāᶜātuhu* 14
2b	*ᶜarḍ* 34	*sāᶜātuhu* 14 19
3a	*ᶜarḍ* 32	*sāᶜātuhu* 14 08
3b	*ᶜarḍ* 36	*sāᶜātuhu* 14 30

The sixth plate face contains four obliquity scales and 16 quarter horizons for latitudes 15°, 16°, 17°, 18°, 25°, 26°, 27°, 28°, 35°, 36°, 37°, 38°, 45°, 46°, 47°, and 48°.

The rete is inscribed with the names of 27 stars. Its design is severely simple, incorporating

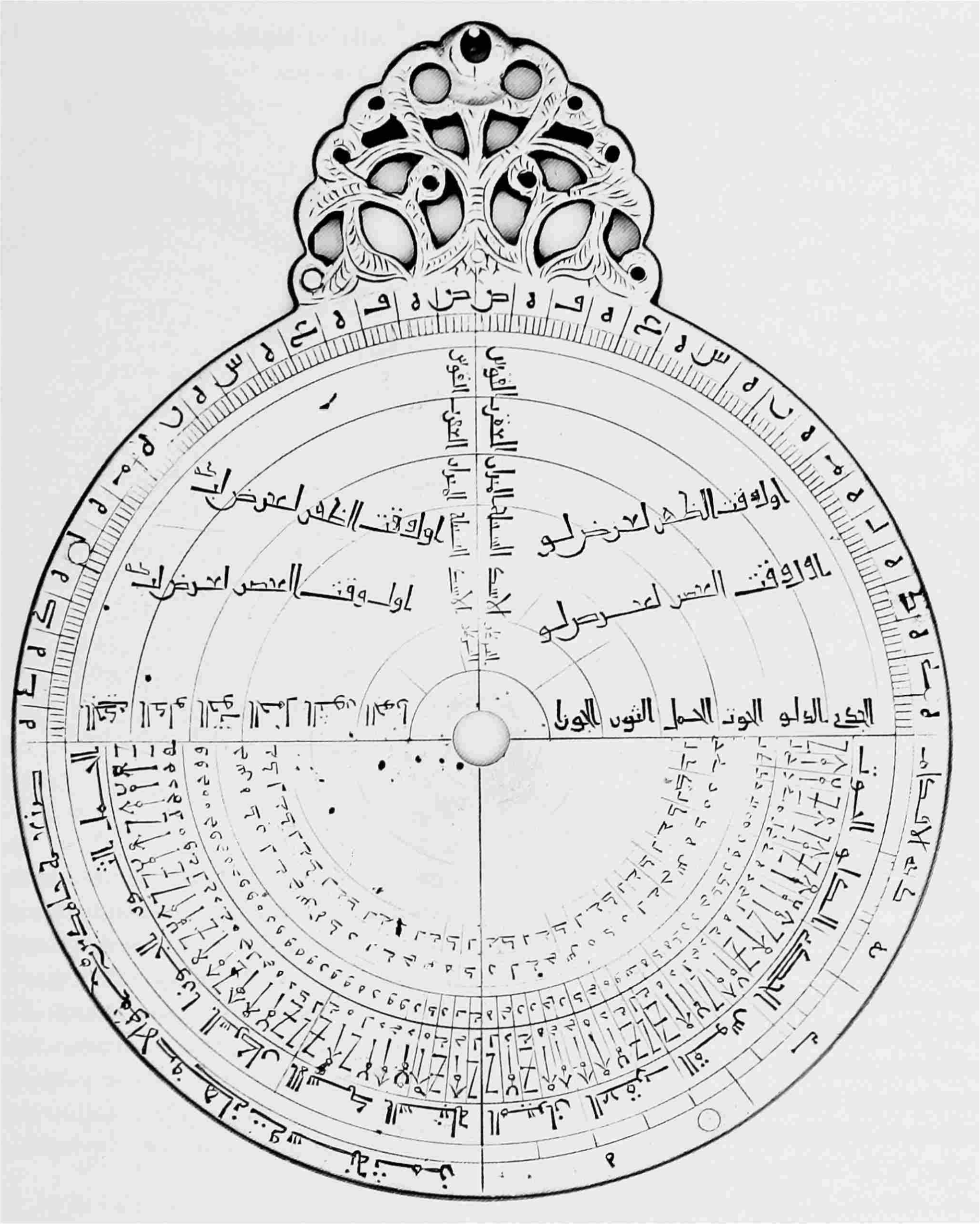


FIGURE 38.—Astrolabe No. 4. Back view.

a non-counterchanged east-west bar and an equinoctial arc. The ecliptic band is subdivided into units of 6°. The star-pointers are dagger-like. The uninscribed alidade is not counterchanged. It includes a beveled fiducial edge and two sighting plates (separated by a distance of 77 mm), each pierced with a single large hole. The pin is a bolt with a flattened head and a doorknob-shaped tip. The wedge is a horse's head, and it includes appropriate engraved details.

The lettering on this instrument is Kufic of the eastern type, and it is consistent throughout.

Remarks: No other astrolabe by Ḥamid is known. Plate 3a is notably more elaborate than the other plate faces. Plates 1 and 3 have each been pierced with two holes near the perimeter at about 54° and 124° The obliquity scale on

plate face 1a is inconsistently inscribed. The segment at 90° is the only one inscribed in standard fashion.

CCA No. 15

(FIGURE 39)

Date: A.H. 774 [1372].

Signature: ṣanaʿahu Jaʿfar ben ʿUmar ben Daulatshah al-Kirmani.

Components: Body with throne, three plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 73 mm.

Material: Brass.

Characteristics: The uninscribed throne is in the shape of a Moorish arch. It is pierced by two small holes placed symmetrically on either side of the handle hole. The rim is divided into 360° with the first unit marked with an *abdjad* "5," the last, "60." A gazetteer containing 21 place names, each associated with longitude, latitude, and distance from Mecca, is engraved in the front central area. Twenty of the place names and parameters are engraved on spiral arms; one name (Mecca) is engraved in the center of the table.

The margins of the back of this instrument contain altitude scales in the upper portion and cotangent scales (fingers left, feet right) in the lower portion. The upper left quadrant is divided by sine lines for each degree. The upper right quadrant contains, in addition to the signature, a shadow square divided into fingers and a box scale of triplicities inscribed:

المثلثات النهار الليل

This translates as follows: "[The Table of] Triplicities [with the Planetary Lords of] Day [and] Night" (GS).

The two lower quadrants contain six semicircular astrological scales (signs, planetary governors of terms, terms, planetary governors of faces, planetary governors of decanates, degrees of decanates).

Except for the horizon face, all of the plate faces are engraved with projections of horizon, altitudes, and unequal hours. One plate face contains in addition projections of azimuths; two faces also contain equal Italian hours; and one face contains additional projections of both azimuth and equal Italian hours. The plate face which contains only horizon, altitudes, and unequal hours contains these projections for two distinct latitudes. The following engraved latitudes and lengths of daylight locate each projection:

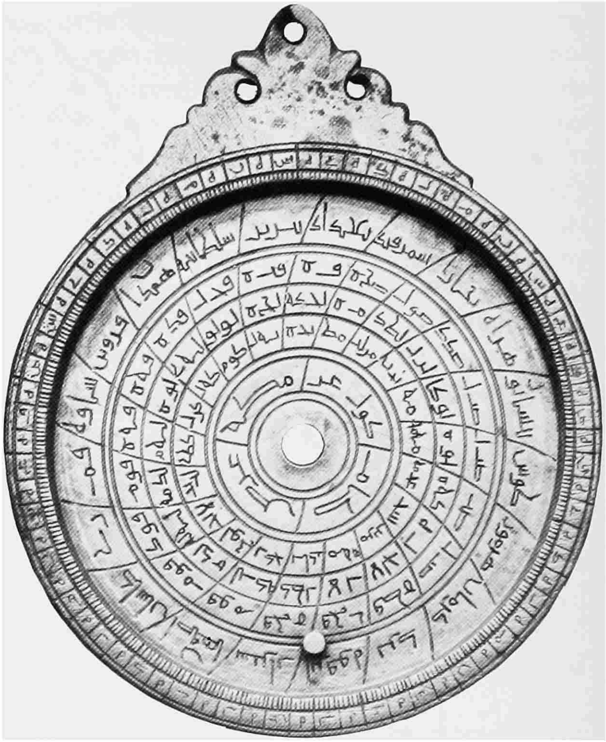


FIGURE 39.—Astrolabe No. 15. Gazetteer.

Plate	*Latitude*	*Length of daylight*
1a	*ʿarḍ* 32	*sāʿātuhu* 14 08
1b	*ʿarḍ* 30	*sāʿātuhu* 13 58
2a	*ʿarḍ* 36	*sāʿātuhu* 14 30
2b	*ʿarḍ* 38	*sāʿātuhu* 14 48
	ʿarḍ 28	*sāʿātuhu* 13 08
3a	*ʿarḍ* 34	*sāʿātuhu* 14 19

The horizon plate face contains 21 quarter horizons for every 6° of latitude from 12° to 84°. Each horizon is identified by inscription. In addition, the curious phrase *al-bum* [*?*] *146*

appears in the lower left quadrant of this plate face, the phrase *al-bum* [?] *114* appears in the lower right quadrant, and *al-bum* [?] *72* in the upper right quadrant.

The rete incorporates 19 dagger- or sickle-shaped star pointers, each inscribed with a star name. The ecliptic is divided into 5° units. The plain alidade has a beveled fiducial edge, diagonal ends, and a central Moorish arch. It is not counterchanged. The sighting plates are each pierced with two equal holes, one above the other. A plane ringlet fits over the pin. The latter has a hemispherical head and doorknob-shaped tip. The wedge is a horse's head, complete with engraved eye and mouth.

The alphabet employed by the maker is Arabic, Kufic throughout.

Remarks: Other astrolabes signed by Ja^cfar ben ^cUmar include CCA Number 16, Indian Museum, Calcutta (dated 790 [1388]); CCA Number 1205, private collection (dated 755 [1354]); and CCA Number 3660, private collection (dated 751 [1350]). This instrument is incomplete. It has no handle or ring. The simple alidade may be a replacement. Ja^cfar ben ^cUmar's gazetteer is arranged in order of increasing longitude beginning with Baghdad just to the left of 90° and reading counterclockwise. No other gazetteer in the collection is ordered in this way. Except for the table of triplicities, none of the astrological tables are titled.

CCA No. 25

(FIGURES 21, 22, 40)

Date: A.H. 1078 [1667].

Signature: namaqahu Muḥammad Mahdi ben Muḥammad Amin al-Yazdi.

Components: Body, handle, five plates, rete, alidade, pin, and wedge.

Diameter: 114 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch. It is decorated front and back with embossed vines and flowers. In addition, on the front, two embossed birds face a central cartouche in which is inscribed the opening words of the quotation from the Koran which includes the word "throne."

وسع كرسيه السموات و الارض

The translation is, "His throne holds the Heavens and the earth" (GS). Above this is a second inscription which reads:

هو الله تعالى

This translates, "He is the most exalted" (GS). At the base of the throne, on the right, the words

يا رافع

"O! You who lifts" (GS) appear; on the left is the word

السماء

"the Heavens" (GS). There is considerable inscription on the back of the throne. It is framed at left, top, and right by the three words *mashriq*, *ḥūt*, and *maghrib*, respectively. In addition to these words, there are inscribed the names of 23 places arranged as follows (beginning at the lower left and proceeding in a clockwise direction): *Bejeh*, *Shahr*(?), *Ḥabashah*, *Mahdiyyah*, *Darnalar*, *Belzar*(?), *Ṭabariyyah*, *Ṭarāblus*, *Ḥalab*, *Āmid*, *Arz Al Rum*, *Damdam*(?), *Shamakh*, *Ṭāliqān*, *Bisṭām*, *Tūn*, *Ḥimṣ*, *Qom*, *Istāneh*, *Ajmer*(?), *Sumiyan*(?), and *Najd*(?). A shallow circular depression 15.5 mm in diameter has been cut into the center of this back face of the throne. The rim of the astrolabe is divided by a scale of 360°. Subdivisions of 5° are identified by *abdjad* numbers from 5 to 360. In the front central area has been engraved a gazetteer listing 46 places, along with the longitude, latitude, azimuth of the Qibla, and direction of the azimuth of the Qibla of each.

On the back of the astrolabe, the upper margin has been divided into two altitude scales. The lower margin contains cotangent scales divided into feet (lower left) and fingers (lower right). At the lowest point in the margin, the following phrase has been engraved:

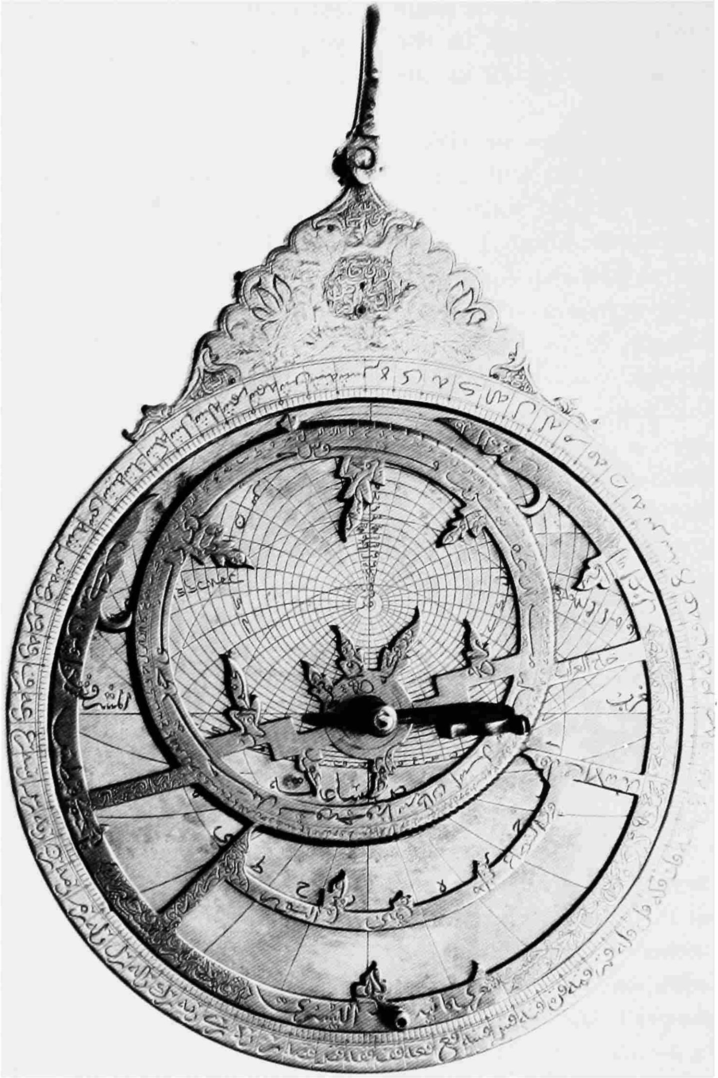


FIGURE 40.—Astrolabe No. 25. Front view.

سنه اسنه جودر وجلو كرست

لوح محفوظ بود تاريخست

Translated this reads: "The familiar year you seek is manifest, 1078 is its date" (GS).

Stereographically-projected declination arcs divide the upper right quadrant. Some of these arcs are defined by dotted lines. Lines representing the altitude of the noon sun have been graphed onto the upper left portion of these declination arcs. The graphed lines are identified with numbers that represent every 3° of latitude from 24° to 48°. The inscription relating to this graph outside the outermost declination arc is transcribed and translated in the description of CCA No. 59. In the lower right portion of this quadrant, the altitudes of the sun when it crosses the azimuth of the Qibla at various times of the year have been graphed. There is one graphed line identified with Ṭus (lowest line), Yazd, Iṣfahan, Hamadan,

Baghdad, and Shiraz. The inscription relating to the graph inside the innermost declination arc is transcribed and translated in the description of CCA No. 49. Sine lines for every degree have been engraved in the upper right quadrant. In this same quadrant, six identified equal hours have been graphed.

Shadow squares divided into feet (left) and fingers (right) occupy the lower quadrants of the back of this astrolabe. The area framed by these squares has been divided into a rectangular table of triplicities. The natures are identified with Arabic terminology. The maker's signature appears in a cartouche below the shadow square. The area between the shadow squares and the marginal cotangent scales contains five semicircular astrological scales: 1) the planetary governors of the terms, 2) the terms, 3) the zodiacal signs, 4) the planetary governors of the faces, and 5) the lunar mansions.

Each of the five plates is notched at 270°. One plate face contains 29 stereographically projected quarter horizons, one for every two degrees of latitude from 10° to 64°. There are, in addition, four obliquity scales at the ends of the stereographically projected colures. All the remaining plate faces contain stereographically projected horizon coordinates for individual latitudes: altitudes (every 3°) and azimuths (every 10°). Eight plate faces contain, in addition to these coordinates, projections of seasonal hour lines. (These are omitted from plate face 3a). On plate faces 3b and 4b, the seasonal hours are identified with the ordinal numbers in Persian. These two faces contain, in addition to seasonal hours, the equal Italian hours. One plate face (4a) contains a projected twilight line. This last is identified with Persian phrases at left and right. Except for the horizon face (5b) and plate face 3a, the plate faces are each identified with a latitude and length of daylight as follows:

Plate	*Latitude*	*Length of daylight*
1a	*ʿarḍ* 32 00	*sāʿatuhu* 14 06
1b	*ʿarḍ* 22 00	*sāʿatuhu* 13 22
2a	*ʿarḍ* 30 00	*sāʿatuhu* 13 58
2b	*ʿarḍ* 35 00	*sāʿatuhu* 14 24
3b	*ʿarḍ* 36 00	*sāʿatuhu* 14 28
4a	*ʿarḍ* 34 00	*sāʿatuhu* 14 17
4b	*ʿarḍ* 37 00	*sāʿatuhu* 14 32
5a	*ʿarḍ* 40 00	*sāʿatuhu* 14 52

Five lines on plate 4b are inscribed as follows: *Samt Qiblat Lar* (at 135°), *Maṣṣiṣyyah* (at 115°), *Lahijan* (at 80°), *Qom* (at 75°), and *Barfurush* (at 70°).

The rete of this astrolabe is quite simple. It consists only of a counterchanged equinoctial bar and a section of the stereographically-projected equator, in addition to the usual ecliptic and Capricorn circles. The latter is decorated with Persian inscriptions.

يا من جعل فى السماء بروجًا •
معدد كرسى وذات البروج است
كه دروى به تفاوت نُه خروجست
ثوابت يك هزار وبيست وجارند
كه بر كرسى مقام خويش دارند

This may be translated as follows: "O! You Who set the zodiac in the heaven. The count includes the throne and the zodiac, that according to some is in nine layers. The fixed stars are one thousand and twenty-four, and each has its own place in the throne" (GS). The ecliptic is subdivided into units of 3°. There are 22 inscribed star pointers. Engraved lines divide the ecliptic on the back of the rete.

The alidade is not counterchanged. It is decorated with vines embossed on a stippled background. The left arm is divided by a sundial scale. The right arm is divided by two scales: one a scale of 60 equal units; the other composed of arcs of stereographically projected declination circles. Two lines of Persian inscription decorate the center of the alidade. Two holes pierce the sighting plates. The pin is a bolt with a hemispherical cap and a doorknob tip. The wedge is in the shape of and is decorated with the details of a horse's head.

The maker employs Arabic Naskhi script throughout.

Remarks: This is one of the most elaborate of the Persian astrolabes in the collection. The decoration on the front face of the throne is most

unusual. At first glance it appears to consist entirely of embossed vines and flowers, but closer study reveals the two facing birds. In addition, above these birds, two "eyes" can be seen to look out under a furrowed "brow." The inscription which appears on the back of the throne is not typical of that found on most Persian astrolabes. Its geographic emphasis supports the notion that the shallow depression once held a magnetic compass. The word *ḥūt* is probably a mistake for *janūbī* (or "south").

In general, *abdjad* numbers are used to identify projected or dividing lines, but Hindu-Arabic numbers identify the unequal hours scale on the back of the instrument and the unequal hours on some plates. Some lines on the back of the astrolabe are dotted for emphasis.

The places in the gazetteer are arranged in a pattern similar to that adopted by makers of other astrolabes in the collection (see, e.g., No. 65.)

The collection includes another, less elaborate astrolabe signed by Muḥammad Mahdi, No. 44.

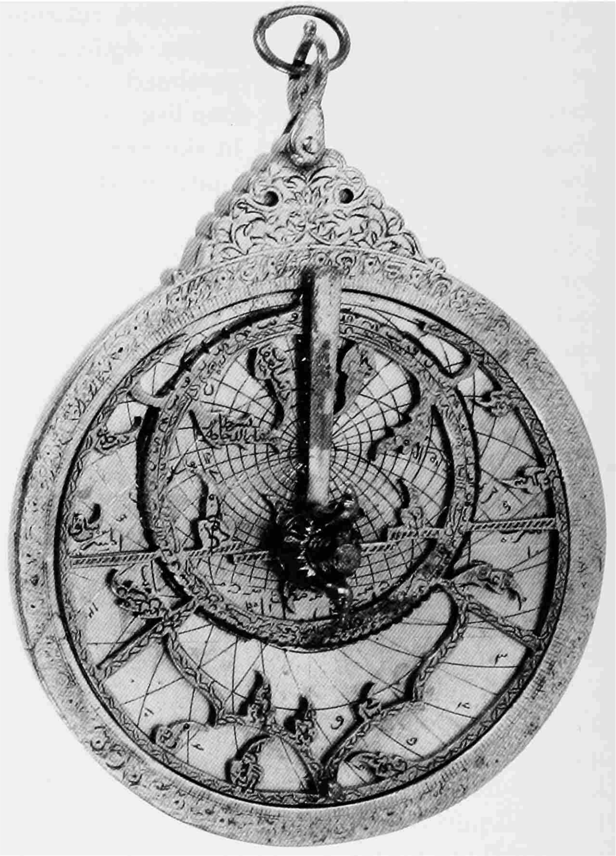


FIGURE 41.—Astrolabe No. 31. Front view.

CCA No. 31

(FIGURE 41)

Date: Ca. A.D. 1715.

Signature: ṣanaᶜahu Muḥammad Amin ben Muḥammad Ṭahir (maker) namaqahuᶜAbd al-Aʾimma (decorator).

Components: Body with throne, handle, ring, five plates, rete, alidade, pin, wedge, and index arm.

Diameter: 74 mm.

Material: Brass.

Characteristics: The throne is a broad, symmetric Moorish arch pierced with two holes. It is decorated front and back with embossed vines and a central flower. The stirrup-shaped handle includes a decorative design above the axle. The ring has a circular cross-section. The rim contains a scale of 360° subdivided into units of 5° identified with *abdjad* numerals. Identifying inscription is embossed on a stippled background. Divisions at 15° intervals (starting at the top) are marked by an embossed "X." The front central area contains a gazetteer consisting of 23 place names along with longitude, latitude, azimuth of the Qibla, and direction of the azimuth of the Qibla for each.

The margin of the back of the astrolabe contains in its upper half two altitude scales; the lower left quadrant contains a cotangent scale divided into feet; the lower right quadrant contains a cotangent scale divided into fingers. The identifying inscription is embossed on a stippled background. The upper right quadrant contains stereographically projected declination arcs upon which are graphed lines marking the altitude of the noon sun at latitudes 32° (leftmost line), 36°, 40°, and 44°, and lines marking the azimuth of the Qibla at Ṭus (lowest line), Iṣfahan, and Qazvin (see CCA Nos. 49 and 59 for transcriptions and translations of the titles of these graphs).

The upper left quadrant is divided by 30 equally spaced sine lines and by 30 equally spaced cosine lines. The chord of this quadrant is marked by a dotted line. Two shadow squares divided into feet (left) and fingers (right) occupy the lower quadrants. There are also four semicircular scales in these two quadrants. One lists the planetary governors of terms; one lists the term divisions; one lists zodiacal signs; and one lists the planetary governors of the faces.

Each of the five plates is notched at 270°. On one plate face 17 quarter-horizons (for every 3° of latitude from 18° to 66°) have been stereographically projected. There are four scales measuring declination, along the ends of the projected colures between the projections of the solstitial circles. All other plate faces contain other stereographically projected arcs in addition to an horizon: altitudes (every 6°), azimuths (every 10°), and unequal hours. On all but one face (2b), the equal Italian hours have also been projected. The faces are identified with various latitudes as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ʿarḍ* 24	*sāʿātuhu* 13 30
2a	*ʿarḍ* 25	*sāʿātuhu* 13 34
2b	*ʿarḍ* 34	*sāʿātuhu* 14 16
3a	*ʿarḍ* 27	*sāʿātuhu* 13 52
3b	*ʿarḍ* 36	*sāʿātuhu* 14 28
4a	*ʿarḍ* 30	*sāʿātuhu* 13 56
4b	*ʿarḍ* 33	*sāʿātuhu* 14 12
5a	*ʿarḍ* 32	*sāʿātuhu* 14 07
5b	*ʿarḍ* 38	*sāʿātuhu* 14 39

Abdjad numerals are used to identify all projected lines on plates except the Italian hours, for which Hindu-Arabic numerals are used.

The rete design includes a counterchanged equinoctial colure, on which diagonal lines have been engraved, and an M-shaped support between ecliptic and lower half of Capricorn circle. A chain of leaves decorates both the Capricorn circle and the support. Twenty-four pointers have been inscribed with star names. The ecliptic has been subdivided into units of 6°. There are some engraved lines including ecliptic divisions still visible on the back of the rete.

The alidade is not counterchanged. Divisions on the right half correspond to the positions of stereographically projected declination arcs; the left half of the alidade contains a partially effaced scale of equal divisions and a partially effaced sundial scale. There is a notch above a hole in each sighting plate. The pin is a screw with a hemispherical head. The wedge is a wing nut. A radial index arm has been attached to the front of this astrolabe. It is thin and narrow, being slightly wider at its outer end than it is at the point where it connects with its attachment ring.

The alphabet employed in inscription is Arabic Naskhi.

Remarks: Other astrolabes, similarly signed, include CCA No. 32, Indian Museum, Calcutta (undated) and CCA No. 1171, City Art Museum, St. Louis (undated). The outer surface of this instrument is quite worn; the plates are thin and bent; the alidade shows signs of having been repaired. The index arm, pin, and wedge are almost certainly not the work of Muḥammad Amin. The towns listed in the gazetteer are a subset of those included in the gazetteer of No. 39.

CCA No. 37

(Figures 24, 42, and 43)

Date: Ca. A.D. 1715.

Signature: ʿAbd al-Aʾimma

Components: Body with throne, handle, ring, four plates, rete, alidade, pin, ring, and wedge.

Diameter: 93.5 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch. Both front and back are decorated with an embossed design consisting of a vine with slender leaves and flowers. On the front this design surrounds a central cartouche. The handle is stirrup-shaped with diamond cross-section. The ring also has a diamond cross-section. The rim is divided into a scale of 360°. The last 5° subdivision is marked "60" in *abdjad* numerals. The front central area contains a gazetteer listing 34 place names along with longitude, latitude, azimuth of the Qibla, and direction of the azimuth of the Qibla for each.

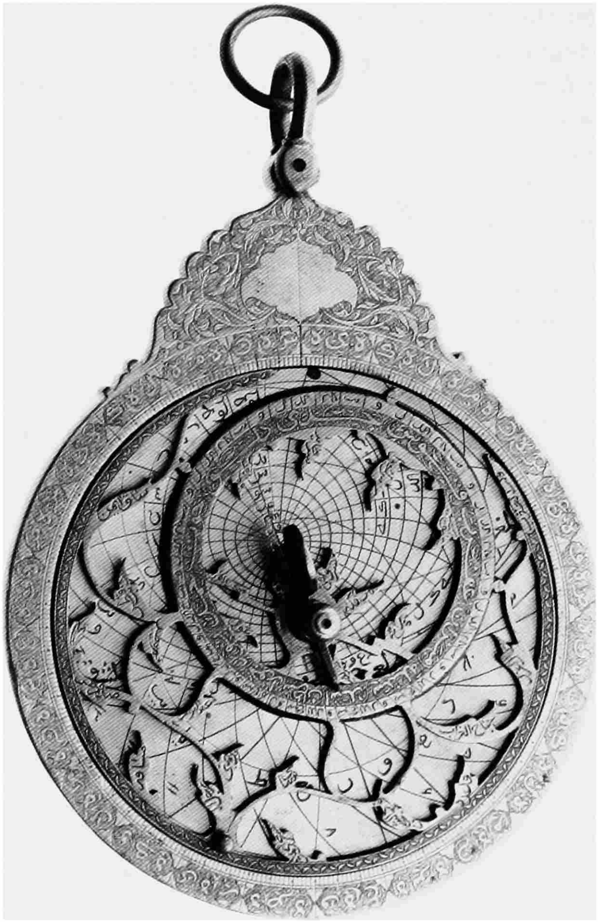


FIGURE 42.—Astrolabe No. 37. Front view.

On the back of the astrolabe, the upper margin contains an altitude scale. The lower margin contains cotangent scales divided into feet (left) and fingers (right). The upper right margin contains stereographically projected declination arcs. On these are graphed lines representing the altitudes of the noon sun for latitudes 28° (left), 30°, 32°, 34°, 36°, 38°, 40°, and lines representing the azimuth of the Qibla for four cities: Ṭus (bottom), Iṣfahan, Baghdad, and Yazd (for a transcription and translation of the inscription on the periphery of the declination arcs, see CCA No. 59; for inscription inside the declination arcs see CCA No. 49). The upper left quadrant contains 60 equally spaced sine lines and 60 equally spaced cosine lines. There are shadow squares divided into feet (left) and fingers (right) in the lower quadrants. There is a scale of triplicities in the rectangle formed by the shadow-square boundary. The scale is entitled:

اربابها بالليل

الطبايع المثلثات اربابها بالنهار

meaning, "Natures, Triplicities, Their Lords in the Day, Their Lords in the Night." Arabic terms have been used to identify the natures. A cartouche below the shadow square contains the signature. Also in the lower quadrants are five semicircular astrological scales: planetary governors of terms, terms, zodiacal signs, planetary governors of faces, and lunar mansions.

There are four plates. Each has a notch at 270°. One plate face contains only scales of declination and stereographically projected semi-horizons for every 3° of latitude from 15° to 66°. Each of the remaining plate faces contains a single stereographically projected horizon and related coordinates: altitudes (every 6°), azimuths (every 10°), unequal hours, and equal Italian hours. The projected networks are identified:

Plate	*Latitude*	*Length of daylight*
1b	*li-ʿarḍ* 29	*sāʿātuhu* 13 52
2a	*li-ʿarḍ* 34	*sāʿātuhu* 14 16
2b	*li-ʿarḍ* 37	*sāʿātuhu* 14 38
3a	*li-ʿarḍ* 30	*sāʿātuhu* 13 56
3b	*li-ʿarḍ* 36	*sāʿātuhu* 14 28
4a	*li-ʿarḍ* 32	*sāʿātuhu* 14 07
4b	*li-ʿarḍ* 38	*sāʿātuhu* 14 36

The rete pattern incorporates an abbreviated counterchanged equinoctial colure (inside the ecliptic). The area between the ecliptic circle and the Capricorn circle contains a vine outlining the shape of an inverted Moorish arch. There are 26 pointers inscribed with star names. The ecliptic is subdivided by units of 6°. The circle of a stereographically projected equator and the divisions of the ecliptic circle are visibly engraved on the back of the rete.

The alidade (no counterchanges) is divided on one arm by arcs corresponding to the stereographically projected declination arcs in the upper right quadrant. There are "sundial" divisions on the other arm, as well as 60 equally spaced divisions

FIGURE 43.—Astrolabe No. 37. Gazetteer.

along the beveled edge. Two holes pierce the sighting plates; the upper is larger. The pin is a bolt with a hemispherical head. The ring is a washer. The wedge is a spiral-decorated bar.

The inscription is in Arabic Naskhi characters. Except for identification of the equal Italian hours using Hindu-Arabic numerals, the scales are identified with *abdjad* numerals.

Remarks: This is a well-made instrument. The maker has used dotted lines for emphasis on some scales on the back. Most lettering is embossed on a stippled background. The four plates are identical in content to four of six included in No. 40.

For other works by the same maker, see No. 39.

CCA No. 39

(FIGURE 44)

Date: Ca. A.D. 1715.

Signature: ṣana^{c}ahu ^{c}Abd al-A$^{\supset}$imma.

Components: Body with throne, handle, ring, cord, three plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 92.5 mm.

Material: Brass.

Characteristics: The throne, a broad, symmetric Moorish arch, has been embossed with inscription on both sides. The front reads,

وسع كرسيه السموات و الارض

"His throne holds the Heavens and the earth" (GS). The back contains a lengthy inscription.

الله . قد تم لاجل سمى ذبيح المولى الاعظم
عمدة ارباب القلم قطب صفحاهى (فصحاهى read
فلك الوزارة ميرزا اسماعيل اسلمه الله .

This may be translated as follows: "[In the name of God.] It has been completed for the sake of the namesake of the person sacrificed [by Abraham] the most excellent master, the most distinguished of the men of pen, the leading pole of the men of eloquence [read *fuṣaḥā*$^{\supset}$], the zodiac [*falak*] of the ministry, Mirza Isma^{c}il may God preserve him" (GS).

The stirrup-shaped handle has a rectangular cross-section. The ring has a circular cross-section. A relatively well-preserved cord, consisting of faded blue, yellow, and lavender threads, is attached to the ring. A worn gold-colored ornament decorates its loose end.

The rim of this instrument is divided by a scale of 360°. Complete *abdjad* numerals identify each 5° division. The front central area contains a gazetteer listing the azimuth of the Qibla and its direction for each of 46 named places, along with their respective longitudes and latitudes.

On the back of this astrolabe, the upper half of the margin is divided into two altitude scales. On them, every fifth degree is marked with a dot. The lower half of the margin contains cotangent scales divided into feet (left) and fingers (right). The lowest part of the margin contains the following phrase inside brackets:

غرض نقشيست كز ما باز ماند

"The intention is to have an image remain after us" (GS). The upper right quadrant contains stereographically projected declination arcs. Two sets of lines have been graphed on these arcs: lines marking the altitude of the noon sun at latitudes 30° (at left), 33°, 36°, 39°, and 42°, and lines marking the azimuth of the Qibla sun at Ṭus (lowest), Yazd, Iṣfahan, Baghdad, and Kufa. For a transcription and translation of the titles of these graphs, see Nos. 49 and 59. Sine lines for every degree divide the upper left quadrant. Six lines marking the unequal hours have also been engraved in this quadrant. Shadow squares divided into feet (left) and fingers (right) have been engraved in the lower quadrants. These quadrants also contain six astrological scales. One of these, the scale of triplicities (Arabic natures; for title see CCA No. 37), fills the area bounded by the shadow squares. The remaining five are semicircular and consist of a scale of planetary governors of terms, terms, zodiacal signs, planetary governors of faces, and lunar mansions. Much of the identifying inscription on the body of the instrument has been embossed on a stippled background.

There are three plates. Two of these are notched at 270° One has four equally spaced notches. There are also 18 quarter horizons (one for every three degrees of latitude from 15° to 66°), which have been stereographically projected onto one face of the multi-notched plate. The remaining plate faces contain, in addition to a single stereographically projected horizon arc, altitudes (every 6°), azimuths (every 10°), unequal hours, and equal Italian hours. The plate faces

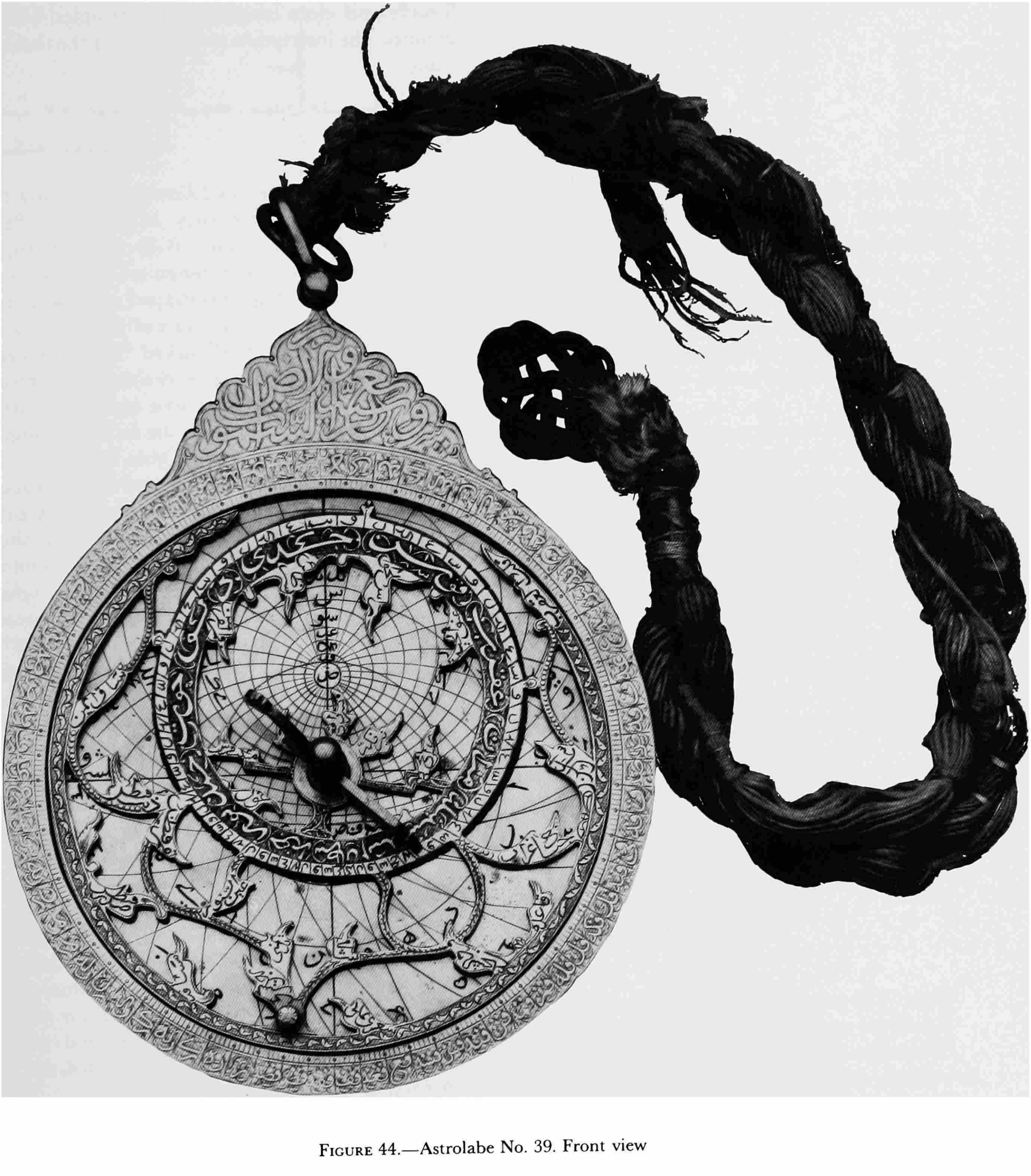


FIGURE 44.—Astrolabe No. 39. Front view

are identified as follows:

Plate	*Latitude*	*Length of Daylight*
1b	^{c}*arḍ* 29	*sā^{c}ātuhu* 13 52
2a	^{c}*arḍ* 30	*sā^{c}ātuhu* 13 56
2b	^{c}*arḍ* 36	*sā^{c}ātuhu* 14 28
3a	^{c}*arḍ* 38	*sā^{c}ātuhu* 14 39
3b	^{c}*arḍ* 32	*sā^{c}ātuhu* 14 07

The rete design includes only the part of the equinoctial colure inside the ecliptic band. It is counterchanged two times. In the area between the ecliptic and Capricorn bands, curling vines form an inverted Moorish arch. Twenty-six star pointers have been inscribed with Arabic star names. The ecliptic is subdivided into units of 6°. There are no visible marks on the back of the rete.

The alidade is not counterchanged. On one arm, six arcs that correspond to the stereographically projected declination arcs in the upper right quadrant have been engraved. The other arm is divided by a scale of equal divisions and by a sundial scale. Each sighting plate has been pierced with two holes, the upper larger than the lower. The pin is a bolt with a hemispherical head and a doorknob tip. The ringlet has a rectangular cross-section. The wedge is a horse-head shape with engraved details.

The alphabet employed by the maker is Arabic Naskhi.

Remarks: The three plates included with this instrument are identical (with respect to content and arrangement) to three of the five plates included with astrolabe No. 40.[103]

CCA No. 40

(Figures 45, 46)

Date: Ca. A.D. 1715.

Signature: ṣana^{c}ahu^{c}Abd al-A$^{\supset}$imma.

Components: Body with throne, handle, ring, five plates, rete, alidade, pin, and wedge.

Diameter: 93.5 mm.

Material: Brass.

Characteristics: The throne, shaped like a Moorish arch, is decorated on the back with flowers and vines embossed on a stippled background. The inscription on the front of the throne reads

حسب الفرموده عاليجاه مهدی قلی بك
زنكنه تمام رسيد

and can be translated as follows: "According to the decree of his excellency Mahdi Qoli Bey Zangeneh this was done" (GS). The stirrup-shaped handle has a rectangular cross-section. The ring has a diamond-shaped cross-section. The rim is divided (at intervals of 5°) by a scale of 360°. The last unit is marked "60" in *abdjad* numerals. Every fifth degree division is marked by a dot. The front central area contains a gazetteer of 34 cities, along with the latitude, longitude, and the azimuth of the Qibla for each.

The upper margin on the back of the astrolabe contains altitude scales. The lower left margin contains a cotangent scale divided into feet; the lower right margin, a cotangent scale divided into fingers. Declination arcs divide the upper right quadrant. Lines marking the altitude of the noon sun for every two degrees of latitude between 28° and 38° and for 42°, and lines marking the azimuth of the Qibla for the cities Ṭus (bottom), Iṣfahan, and Baghdad have been graphed on the declination circles. For a transcription of the inscription outside the outermost declination arc, see CCA No. 59. For a transcription of the inscription inside the innermost declination arc, see No. 49. The upper left quadrant is cross-hatched by sexagesimal sines and cosines. Shadow squares divided into feet (lower left) and fingers (lower right) divide the lower quadrants. Outside the shadow squares there are semicircular astrological scales of planets, terms, signs, faces, and mansions. Inside the shadow squares is a rectangular scale of triplicities. The natures are identified with Arabic terms. The signature is enclosed in a cartouche below the shadow square.

There are five plates, each notched at 270°. One plate face contains quarter horizons, one for every 3° of latitude between 12° and 66°, and a scale of obliquity divided into units of 6° The

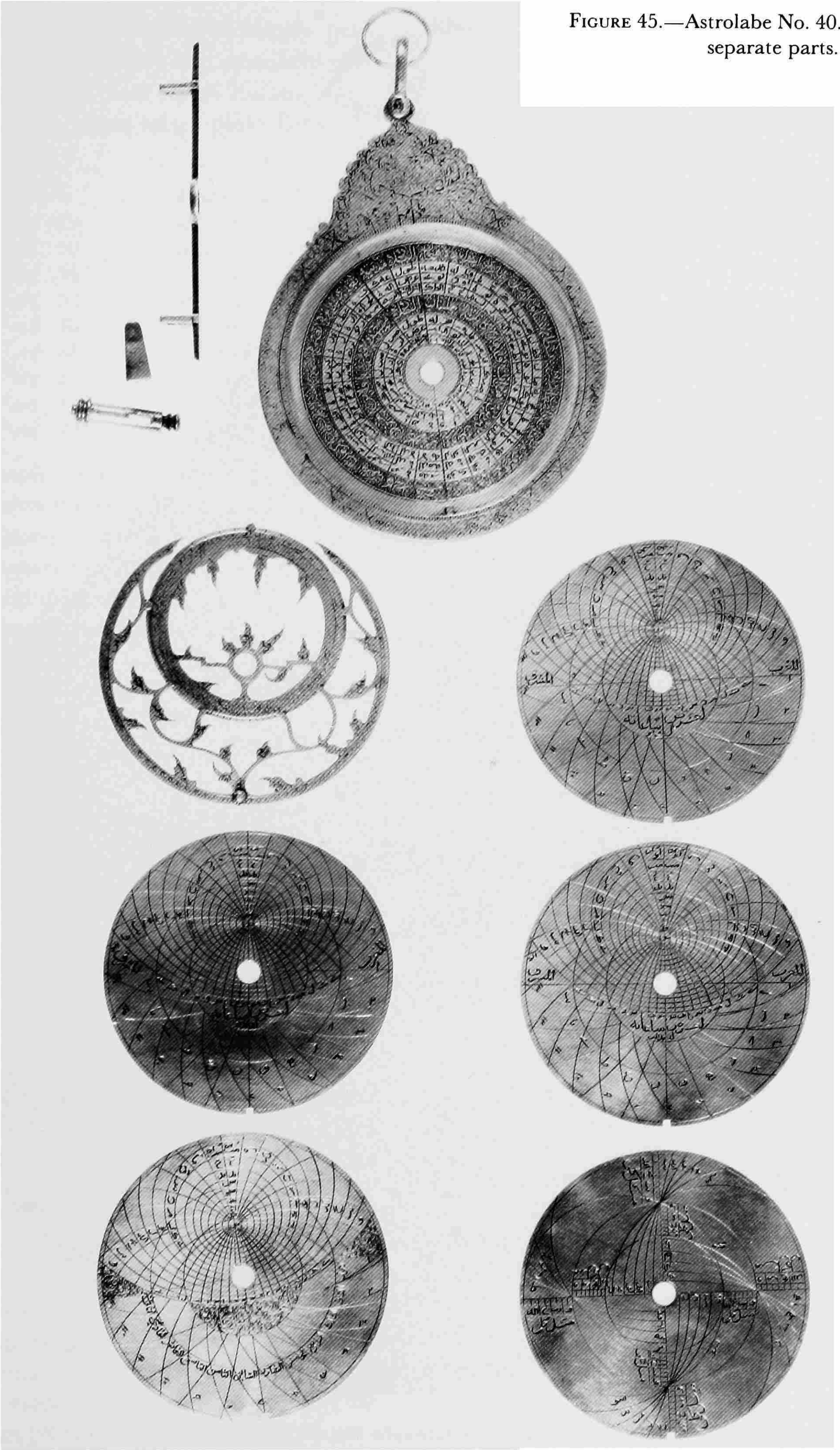


FIGURE 45.—Astrolabe No. 40. Front view of separate parts.

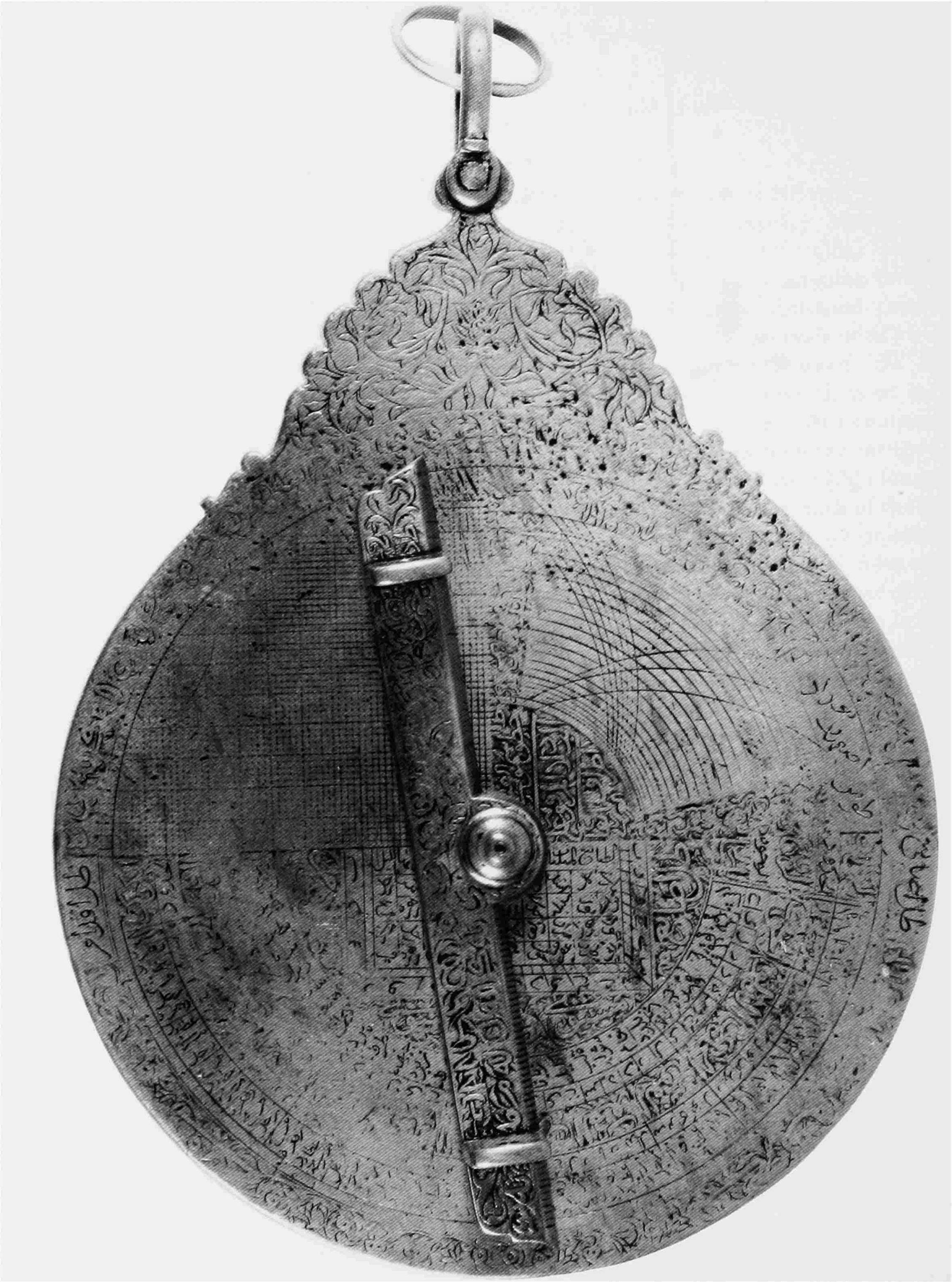


FIGURE 46.—Astrolabe No. 40. Back view.

remaining faces contain stereographically projected horizon, altitudes (every 6°), azimuths (every 10°) unequal hours, and equal Italian hours for a single latitude. These latter plate faces are inscribed as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ᶜarḍ* 29	*sāᶜātuhu* 13 52
2a	*ᶜarḍ* 30	*sāᶜātuhu* 13 56
2b	*ᶜarḍ* 36	*sāᶜātuhu* 14 28
3a	*ᶜarḍ* 32	*sāᶜātuhu* 14 07
3b	*ᶜarḍ* 38	*sāᶜātuhu* 14 39
4a	*ᶜarḍ* 34	*sāᶜātuhu* 14 16
4b	*ᶜarḍ* 37	*sāᶜātuhu* 14 38
5a	*ᶜarḍ* 35	*sāᶜātuhu* 14 22
5b	*ᶜarḍ* 40	*sāᶜātuhu* 14 51

The very simple rete pattern consists of a bracket in the area between the ecliptic and the Tropic of Capricorn. There is a portion of counterchanged east-west bar inside the ecliptic. The ecliptic band is subdivided into units of 6°. There are 28 flame-shaped star pointers, each inscribed with a star name. Straight lines and ecliptic divisions have been engraved on the back of the rete. The alidade arm is not counterchanged. One arm is inscribed with sundial divisions.The other arm is divided by a scale of 60 equal divisions along the beveled edge and by lines coinciding with the stereographically projected declination arcs. The sighting plates are pierced with two holes, with the upper larger. The pin is a bolt with a doorknob-shaped head and tip. The wedge is a simple uninscribed trapezoid.

The maker has employed Arabic Naskhi script with some Hindu-Arabic numerals (equal Italian hours).

Remarks: Most lettering is embossed on a stippled background. The maker has used dotted lines only on the declination scale. Plates 1, 2, and 3 of this instrument are identical to the three plates of CCA No. 39, also by ᶜAbd al-Aᵓimma. The selection and arrangement of place names in the gazetteer follows the pattern adopted by the maker of CCA No. 25. The surface of the body of this example is quite worn, but there are no signs of repair. The engraving is excellent. Note the possibility of an error in the inscribed number of unequal hours on plate face 5b.

CCA No. 42

(FIGURES 47, 48)

Date: Ca. A.D. 1795.

Signature: ṣanaᶜahu Ḥajji ᶜAli.

Components: Body with throne, handle, ring, six plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 91 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch. It is decorated on front and back with embossed leaves and vines surrounding a large central flower. The handle is a narrow stirrup. There is a scale of 360° on the rim. The first division is marked "5," the last, "60" (in *abdjad* numerals). Inside the front central area there is a tooth at 270° In addition, there is a

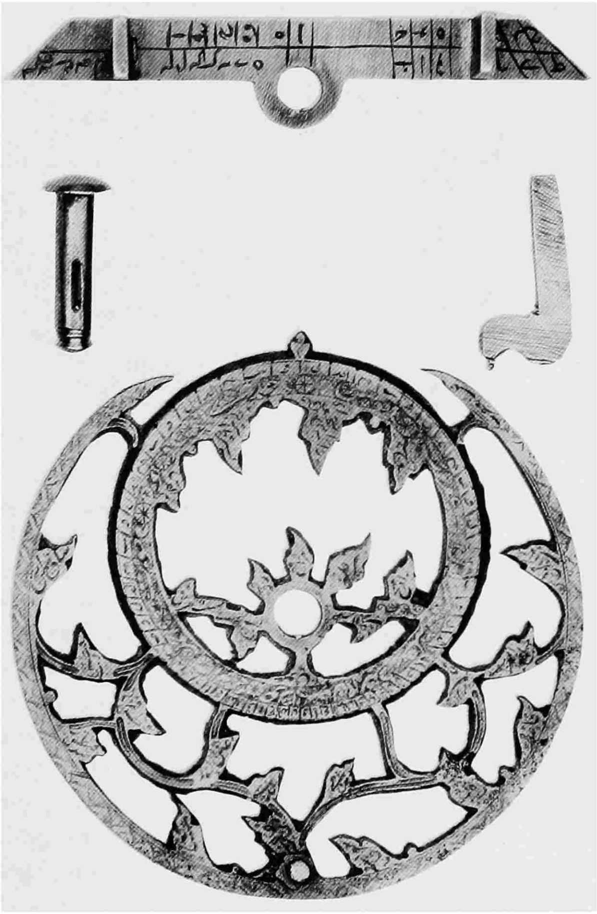


FIGURE 47.—Astrolabe No. 42. Alidade (top) and *ᶜankabūt*.

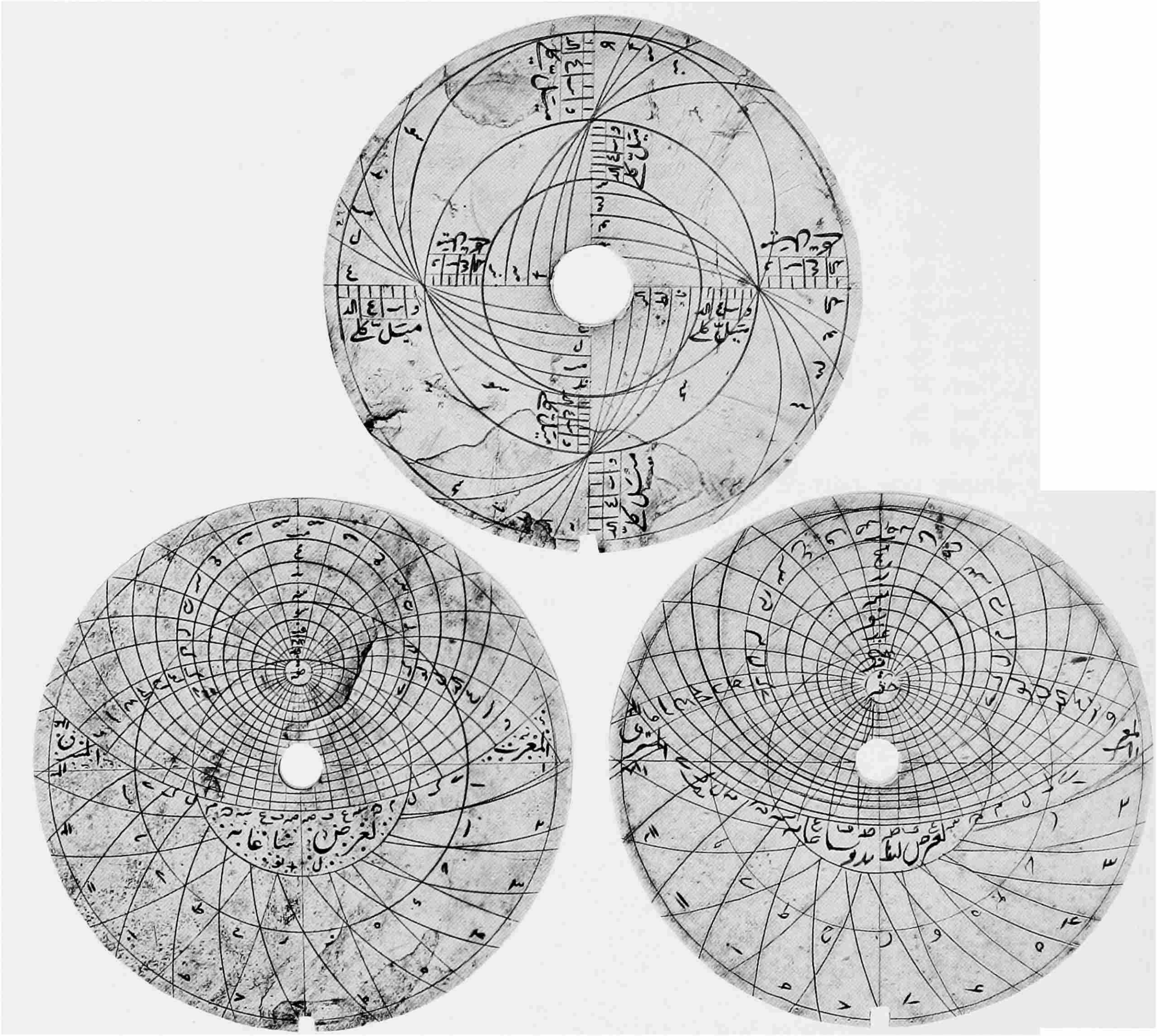


FIGURE 48.—Astrolabe No. 42. Plates, including plate for multiple latitudes (top), for latitude 30°, and for latitude 32°

gazetteer listing 34 places and including for each, longitude, latitude, and azimuth of the Qibla.

The upper margin on the back of the astrolabe contains altitude scales. The lower margin contains cotangent scales divided into feet (left) and fingers (right). There is a stereographically projected declination scale in the upper right quadrant. Lines marking the azimuth of the Qibla have been engraved upon the declination arcs. The azimuth lines are identified with the following cities: Ṭus (lowest), Iṣfahan, Baghdad, and Shiraz. For a transcription and translation of th inscription relating to this scale, see CCA No. 49 Lines marking the altitude of the noon sun fo every 2° of latitude between 28° (at left) and 40 are also graphed onto the declination arcs. For transcription and translation of the inscriptio relating to these lines, see CCA No. 59. In th upper left quadrant, sines and cosines have bee engraved at sexagesimal intervals. The lowe quadrants contain shadow squares divided int feet (left) and fingers (right). There is a scale o

triplicities inside these. The title of the scale is transcribed and translated in the description of No. 37. Both Arabic and Persian terms are used to identify natures. The signature occupies a cartouche below the shadow square. Five semicircular astrological scales have been engraved outside the shadow squares. These include the planetary governors of terms, the degree divisions of terms, the zodiacal signs, the planetary governors of faces, and the lunar mansions. The margin contains the following inscription at 270°:

عمل خامس عشر

It reads: "Fifteenth work" (GS).

Six plates fit into the front central area. All have a notch at 270°. One plate face is inscribed with 17 stereographically projected quarter horizons, representing every 3° of latitude between 15° and 66°. There are four declination scales on this face as well. All the other faces contain stereographically projected coordinates for a single latitude. These include altitudes (every 6°), azimuths (every 10°), unequal hours, and equal Italian hours. The faces are identified as follows:

Plate	*Latitude*		*Length of daylight*	
1b	*ᶜarḍ*	29	*sāᶜatuhu*	13 52
2a	*li-ᶜarḍ*	25 00	*sāᶜatuhu*	13 24
2b	*li-ᶜarḍ*	32 00	*sāᶜatuhu*	14 08
3a	*li-ᶜarḍ*	29 26	*sāᶜatuhu*	13 55
3b	*ᶜarḍ*	32 00	*sāᶜatuhu*	14 06
4a	*ᶜarḍ*	30	*sāᶜatuhu*	13 56
4b	*ᶜarḍ*	36	*sāᶜatuhu*	14 28
5a	*ᶜarḍ*	32 20	*sāᶜatuhu*	14 08
5b	*ᶜarḍ*	36 00	*sāᶜatuhu*	13 26
6a	*ᶜarḍ*	32	*sāᶜatuhu*	14 08
6b	*ᶜarḍ*	38	*sāᶜatuhu*	14 39

The simple rete pattern includes a counterchanged equinoctial colure inside the ecliptic band. There is a curling vine springing from the lowest point of the Capricorn circle. The Capricorn circle is itself decorated with a zig-zag design. The ecliptic is subdivided into units of 6°. There are 29 inscribed star pointers. The alidade is not counterchanged. One arm is divided into six equal units. The other arm contains two scales: one (along the beveled edge) consisting of 12 equal divisions; the other, of 6 unequal divisions. Each sighting plate is pierced by two holes. The pin is a bolt with hemispherical head and knob-shaped tip. There is a washer-shaped ringlet. The wedge is shaped like a bird.

The inscription is in Arabic Naskhi; Hindu-Arabic numerals identify the equal hours on the plates.

Remarks: At least 12 known astrolabes have been signed by this maker. Three of these are in the United States: CCA No. 3509, private collection (undated); CCA No. 3614, Hayden Planetarium, New York City (undated); and CCA No. 3678, private collection (undated). Dated astrolabes by ᶜAli were made in A.H. 1203 [1788], 1205 [1790], 1206 [1791], 1207 [1792], and 1208 [1793].[104]

The pattern of the rete of this astrolabe is remarkably similar to patterns adopted by several other makers at work in Iṣfahan, including ᶜAbd al-Aʾimma (Nos. 37, 39, and 40). Some of the plates of this instrument are less carefully engraved than others (plates 2, 3, 5, and 6). The alidade is a very inaccurately engraved replacement.

CCA No. 44

(FIGURE 49)

Date: Ca. A.D. 1660.

Signature: Muḥammad Mahdi.

Components: Body with throne, handle, ring, five plates, rete, alidade, pin, and wedge.

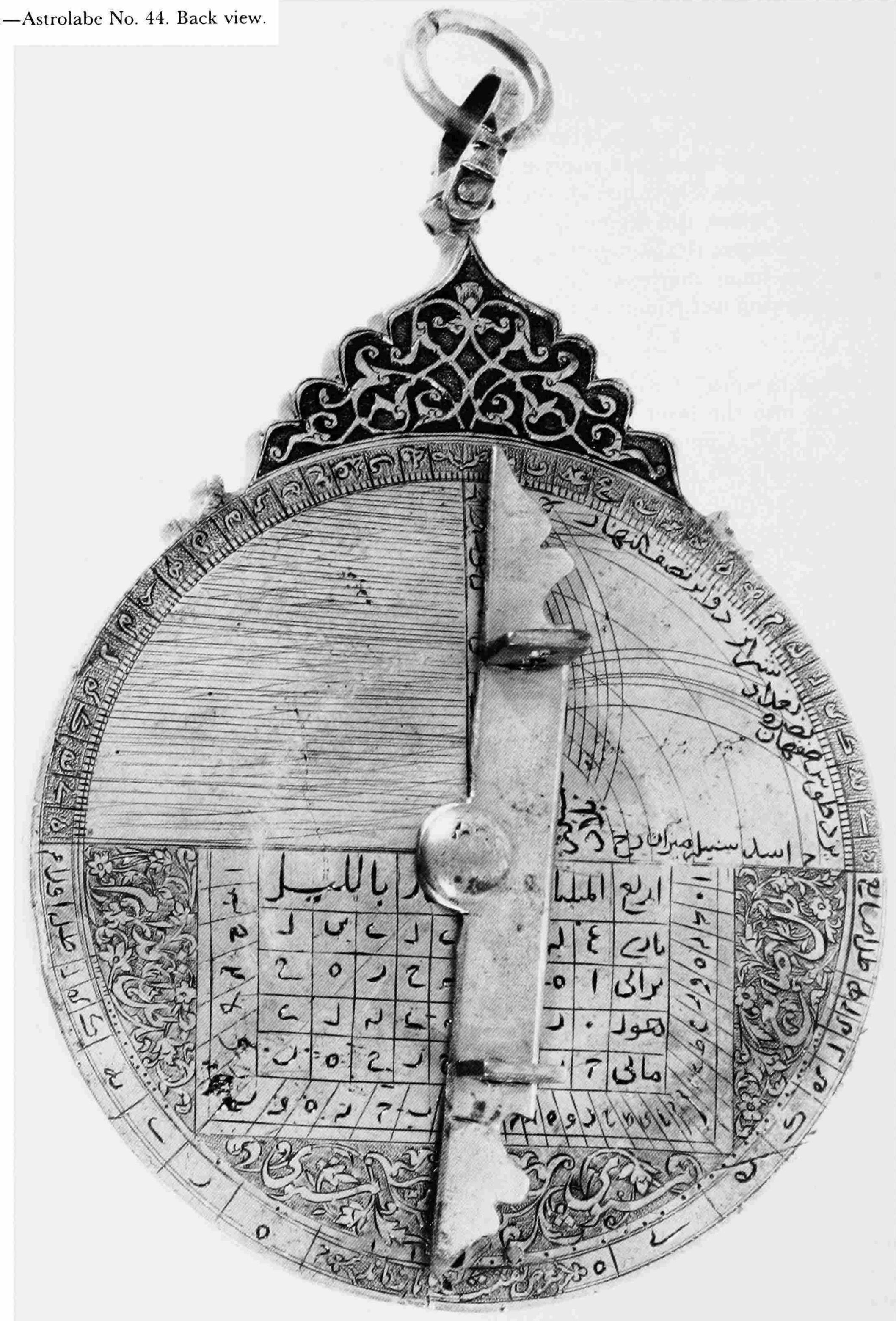
Diameter: 88 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch. A symmetric floral arrangement has been embossed on the front; a symmetric vine with bifid flowers has been embossed on the back. The rim contains a scale of 360° The first division is marked "5," the last, "60," in *abdjad* numerals. The front central area contains a gazetteer listing 50 places, along with the longitude, latitude, the azimuth of the Qibla, and the direction of the azimuth of the Qibla for each.

On the back of the astrolabe, the upper margin is divided by altitude scales. The lower margin contains cotangent scales divided into feet (left)

FIGURE 49.—Astrolabe No. 44. Back view.



and fingers (right). The first two divisions of these latter scales contain the following inscription:

غرض نقشيست كز ما باز ماند

Translated, it reads: "The intention is to have an image remain after us" (GS).

The upper right quadrant contains a set of six stereographically projected declination arcs. Two different sets of lines have been graphed on these arcs. Those graphed in the upper portion of this quadrant are identified from left to right with the numbers 27, 30, 33, 36, 39, 42, and 45; they can be associated with an inscription outside the outermost declination band, which reads "The circles of mid-day" (see CCA No. 59 for transcription). The lower graphed lines are identified as follows (beginning with the lowest): Yazd, Ṭus, Iṣfahan, Baṣra, Baghdad, Shiraz. These lines can be associated with an inscription inside the innermost declination circle, which reads, "The lines of the azimuth of the Qibla at the cities." (See CCA No. 49 for transcription.)

Sixty equally spaced sine lines divide the upper left quadrant. The shadow squares in the lower quadrants are divided into feet (left) and fingers (right). Inside these squares is a box scale of triplicities consisting of four rows and 10 columns. The scale is identified with the following inscription:

اربع المثلثات نهار بالليل

In translation this is, "Quadrant of Triplicities [with the Planetary Lords of] Day [and] Night" (GS). Both Persian and Arabic terms are used to specify the natures, which are fiery, earthy, airy, and watery.

نارى
ترابى
هوا
مائى

A cartouche below the shadow square contains the signature.

One of the four plates is notched four times at the ends of the stereographically projected solstitial and equinoctial colures. The remaining four plates are notched only once at their lowest point. One face of the multinotched plate contains 24 stereographically projected horizon segments, one for every 3° of latitude between 3° and 66° The remaining plate faces each contain stereographically projected coordinates for individual latitudes; the parameters include altitudes (every 6°), azimuths (every 10°), and unequal hours. The plate faces are identified with the following inscriptions:

Plate	*Latitude*		*Length of daylight*	
2a	*li-ᶜarḍ*	23 00	*sāᶜātuhu*	
2b	*ᶜarḍ*	30 00	*sāᶜāt*	
3a	*li-ᶜarḍ*	27 00	*sāᶜātuhu*	
3b	*li-ᶜarḍ*	34 00	*sāᶜātuhu*	14 20 [?]
4a	*ᶜarḍ*	33	*sāᶜātuhu*	14 25
4b	*ᶜarḍ*	34	*sāᶜātuhu*	
5a	*ᶜarḍ*	37 00	*sāᶜātuhu*	
5b	*ᶜarḍ*	36 00	*sāᶜātuhu*	

The projection on the back of the horizon face is unidentified.

The pattern of the rete includes a counterchanged equinoctial bar inside the ecliptic and vines forming an inverted Moorish arch in the are between the ecliptic and the Tropic of Capricorn. There are 29 inscribed star pointers. The ecliptic is subdivided into units of 6°. Some circles and arcs radiating from the center have been engraved on the back of the instrument.

The alidade is neither counterchanged nor inscribed. The pin is a bolt with hemispherical head and knob tip. The wedge is duck-shaped.

The alphabet used in the inscriptions is Arabic Naskhi.

Remarks: The workmanship on this instrument is of varying quality. For example, the gazetteer is beautifully engraved, with the places arranged (with a few exceptions) in order of increasing latitude. However, the lines on the

back of the astrolabe—especially the upper left quadrant—show signs of less careful work. The azimuth lines on all plate faces are of very poor quality. On the horizon plate, the outermost arc in each quadrant is identified as "66." The rete shows signs of having been cast. Its central hole is slightly off center. Other astrolabes in the collection with retes similar to this one are Nos. 37, 39, 40, 59, and 65. There is every reason to believe that the alidade, pin, and wedge are replacements.

If this instrument is indeed the work of its signer, Muḥammad Mahdi, it is not his best effort. Mahdi's signature appears on 21 other known astrolabes. In some cases he is specifically designated "decorator" or "engraver." Two of Mahdi's other works are preserved in the United States: one (signed and dated) is No. 25 in this catalog; the other, CCA No. 2545, (signed) is preserved at the Adler Planetarium in Chicago.

CCA No. 47

(FIGURES 50, 51)

Date: Ca. 1700.

Signature: None.

Components: Body with throne, handle, ring, four plates, rete, alidade, pin, and wedge.

Diameter: 95 mm.

Material: Brass.

Characteristics: The throne, shaped like a Moorish arch, is undecorated and uninscribed. The handle is stirrup-shaped with half hexagonal cross-section. The ring has a circular cross-section. The rim is divided into four scales of 90° inscribed with *abdjad* numerals, each proceeding in a clockwise direction starting at 90°, 0°, 270°, and 180°. A gazetteer has been engraved in the front central area. It consists of 24 place names with longitudes, latitudes, and azimuths of the Qibla. The following phrases have been engraved in the middle of the gazetteer, diametrically opposite each other: the first,

جنوبی غربی

means "southeast," the second,

جنوبی شرقی

is "southwest."

On the back of the instrument, the upper margin contains altitude scales. The lower margin contains cotangent scales divided into feet (left) and fingers (right). One upper quadrant contains stereographically projected declination arcs. The following phrase is written inside these arcs in the upper right quadrant:

بداية بروج وخط سمت قبلة

"The beginning of the signs and lines of the Qibla" (GS). The upper left quadrant is divided by the sines of the angles at increments of 5° and by radii which divide the quadrant into five-degree angles. Shadow squares divided into feet (left) and fingers (right) have been engraved in the two lower quadrants. Also in the lower quadrants there are six bands suitable for astrological scales. Only two, a scale of lunar mansions and a scale of zodiacal signs are complete.

Each of the four plates has a tooth at 270°. One face on one of these (1a) contains only stereographically projected semi-horizons, 37 in all, between 19° and 66°. Face 1b contains only stereographically projected colures, tropics, and equator. All other plate faces contain a single stereographically projected horizon and altitudes (every six degrees). Three plate faces (2a, 2b, 3b) also contain azimuths (every ten degrees) and unequal hours. Five plate faces (all except 1a, 1b, 2a) contain equal Italian hours. The plates are identified as follows:

Plate	*Latitude*	*Length of daylight*
1a	*ṣafīḥah āfāqī*	
1b	*ᶜarḍ tisᶜīn*	
2a	*ᶜarḍ* 30	*sāᶜātuhu* 13 42
2b	*ᶜarḍ* 42	*sāᶜātuhu* 15 05
3a	*ᶜarḍ* 34	*sāᶜātuhu* 14 17
3b	*ᶜarḍ* 36	*sāᶜātuhu* 14 27
4a	*ᶜarḍ* 37	*sāᶜātuhu* 14 00
4b	*ᶜarḍ* 38	*sāᶜātuhu* 14 40

The rete design includes a complete equinoctial colure and a complete celestial equator. Other supporting strapwork is in the shape of twining vines. There are 17 star pointers engraved with Arabic star names. The ecliptic circle is subdivided into units of 6°. Equator and Cancer circles have been engraved on the back of the rete.

The alidade is not counterchanged. It is unin-

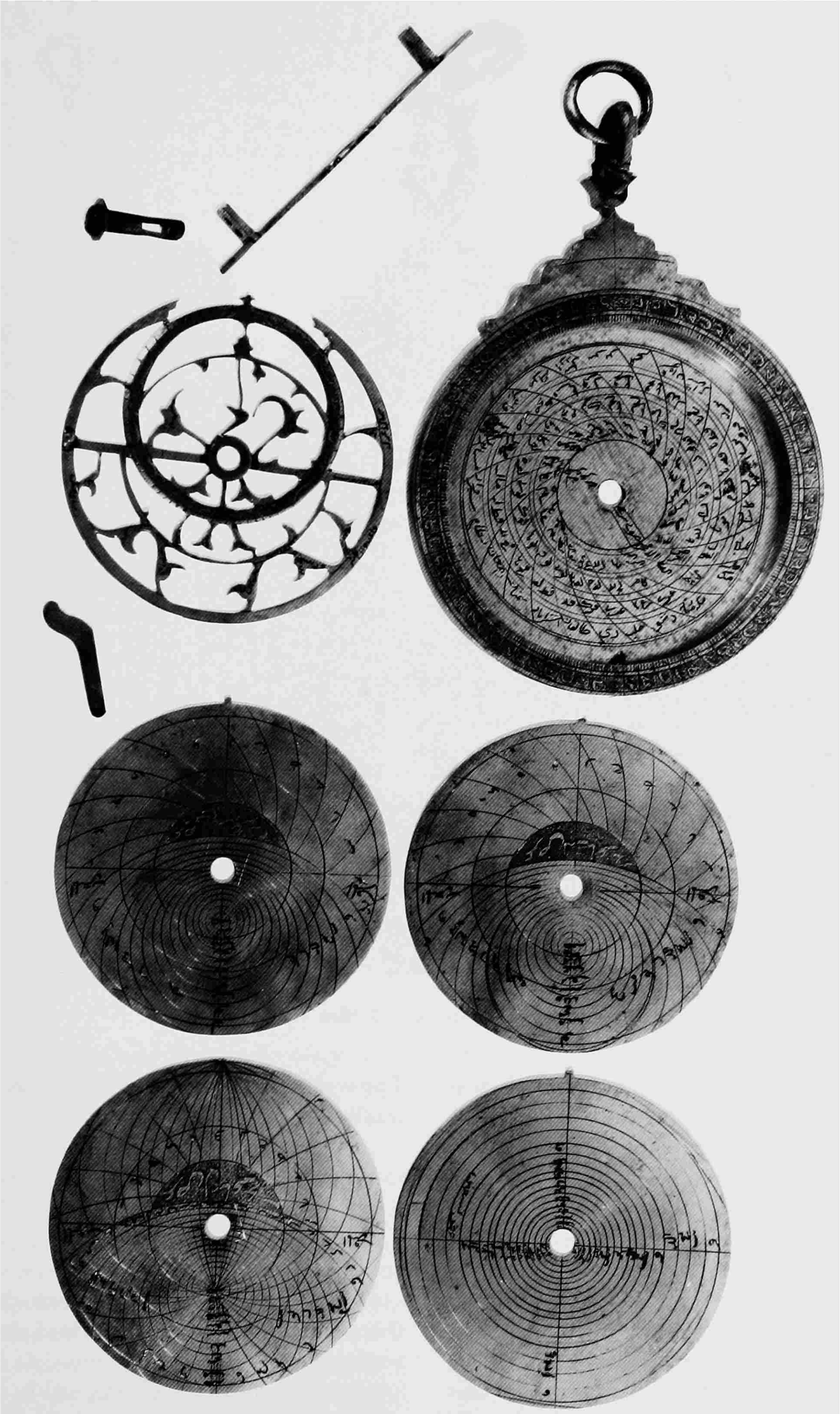


FIGURE 50.—Astrolabe No. 47. Front view of separate parts.

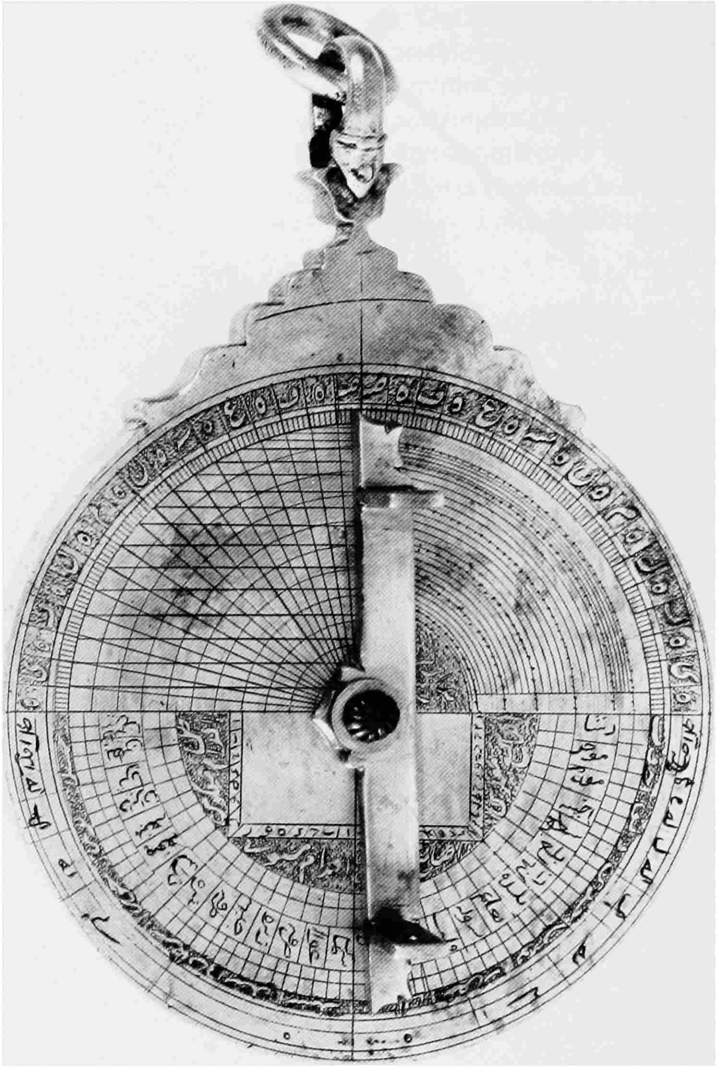


FIGURE 51.—Astrolabe No. 47. Back view.

scribed. Each sighting plate is pierced with two holes; the upper is larger. The pin is a bolt with hemispherical head. The wedge is a stylized horse's head.

The alphabet used by this maker is Arabic Naskhi. Hindu-Arabic numbers identify altitudes on one plate face.

Remarks: Gunther attributes this instrument to Faḍl ʿAli. One astrolabe signed by this man is preserved in the Museum of the History of Science, Oxford, England (CCA No. 46). On one plate of the instrument described here (plate 2) the tooth is broken. The body appears unfinished. The workmanship is not consistently of the finest quality.

CCA No. 49

(FIGURES 30, 52, 53)

Date: See "Remarks."

Signature: None.

Components: Body with throne, handle, ring, five plates, rete, alidade, pin, and wedge.

Diameter: 116 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch. It is relatively broad and symmet-

FIGURE 52.—Astrolabe No. 49. Front view.

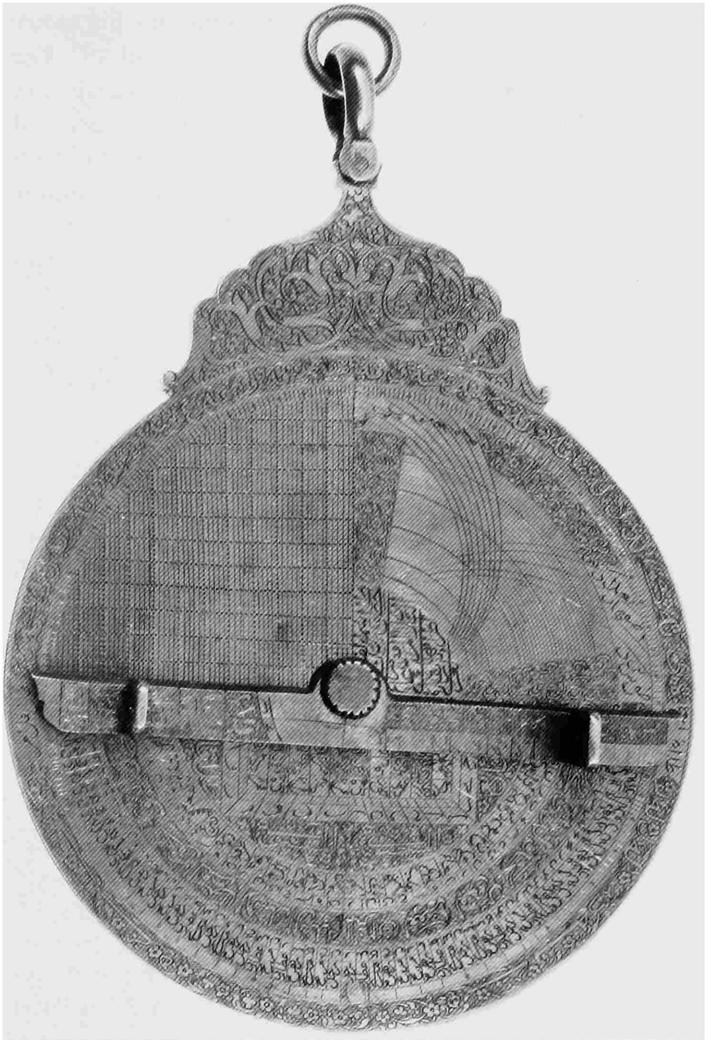


FIGURE 53.—Astrolabe No. 49. Back view.

rical. Embossed vines and flowers decorate front and back. The handle is stirrup-shaped with a double-lunate cross-section. The ring also has a double-lunate cross-section. The rim is divided by a scale of 360° The first unit is identified with an *abdjad* "5," the last, with a "60." There is a tooth projecting into the front central area at 270°. A gazetteer has been engraved on this area. It lists 38 places along with the longitude, latitude, and azimuth of the Qibla for each.

There are altitude scales in the upper margin on the back of the astrolabe. The lower margin contains cotangent scales divided into feet (left) and fingers (right). The declination scale in the upper right quadrant is stereographically projected. Five lines marking the azimuth of the Qibla for Ṭus (bottom), Yazd, Iṣfahan, Baghdad, and Shiraz have been graphed on the declination arcs. The inscription relating to this graph (inside the innermost declination band) reads:

خطوط سموت القبلة فى البلاد المرقومة على
اطرافها بالارتفاع الغربى

It can be translated: "Lines of Qibla directions in the cities marked on the edges in the western altitude" (GS).

Also graphed on the declination arcs are lines

marking the altitude of the noon sun for every two degrees of latitude between 28° and 42°. For a transcription and translation of the inscription relating to this graph, see No. 59. Both sines and cosines have been engraved at sexagesimal intervals in the upper left quadrant. The shadow squares in the lower quadrants have been divided into feet (left) and fingers (right). A triplicities scale, identified as

الطبايع المثلثات اربابها بالنهار
اربابها بالليل

has been engraved inside the shadow squares. Its translation reads: "The natures of the triplicities [and the] Lords [of the] Day [and the] Lords [of the] Night" (GS). Arabic terms are used to specify the natures. The five semicircular astrological scales engraved outside the shadow squares are the planetary governors of the terms, the term divisions in degrees, the zodiacal signs, the planetary governors of faces, and the lunar mansions.

The five plates belonging to this instrument are each notched at 270°. Twenty-one semihorizons have been engraved on one face, representing every three degrees of latitude between 9° and 66°. On this same face, there are four declination scales. Other faces contain stereographically projected coordinates for a single latitude. On six of these, the coordinates include altitudes (every 3°), azimuths (every 10°), and unequal hours. Faces 2b, 3b, and 4b contain these coordinates as well as the equal Italian hours. The single latitude faces are identified with the following inscription:

Plate	*Latitude*		*Length of daylight*	
1b	*li-ᶜarḍ*	29	*sāᶜātuhu*	13 52
2a	*li-ᶜarḍ*	30	*al-sāᶜāt*	13 56
2b	*li-ᶜarḍ*	36	*sāᶜātuhu*	14 28
3a	*li-ᶜarḍ*	34	*sāᶜātuhu*	14 16
3b	*li-ᶜarḍ*	37	*sāᶜātuhu*	14 33
4a	*li-ᶜarḍ*	38	*sāᶜātuhu*	14 39
4b	*li-ᶜarḍ*	32	*sāᶜātuhu*	14 07
5a	*li-ᶜarḍ*	31	*al-sāᶜāt*	14 01
5b	*li-ᶜarḍ*	40	*sāᶜātuhu*	14 51

The rete pattern is formed by curling vines. It includes a branching vine which springs from the lowest point on the Capricorn circle, and it includes, inside the ecliptic, two vines which form a design in the shape of the number "88." The ecliptic is subdivided into units of three degrees. There are 29 inscribed star pointers. The ecliptic has been divided on the back of the rete, but these divisions do not correspond to the divisions on the front of the rete. The alidade is not counterchanged. There are, on the one arm, parts of stereographically projected declination arcs. There are twelve equal divisions along the bevelled edge of the other arm. Five unequal, sundial divisions have been engraved along the flat edge of this arm. Each sighting plate is pierced with two holes of equal size. The pin is a bolt with a flat edge and a doorknob-shaped tip. The wedge has a trapezoidal shape.

The inscription is Arabic Naskhi. However, Hindu-Arabic numerals identify the equal hours.

Remarks: Clues to the date of this astrolabe are provided by the pattern of its rete. The "88" design was adopted by a number of makers at work in Iṣfahan in the early eighteenth century. Prominent among these are ᶜAbd al-Aᵓimma (see CCA Nos. 11 and 38) and ᶜAbd al- ᶜAli (see CCA Nos. 10 and 33). That this instrument was made after these examples is evidenced by the slightly less exacting workmanship. The decorative details are typical of Persian astrolabes, including bracketing of scale divisions and embossed lettering and decoration on stippled background, but the workmanship is unexceptional. There are errors in the inscription of the marginal scales on the back of the astrolabe; a correction occurs in the scale of zodiacal signs. The plates are characterized by errors in the placement of altitudes and the inscription of azimuths. There are also some errors in the hour lines. There is an error in the division of the ecliptic band on the rete (Leo has too few and Sagittarius too many divisions). The maker has used some dotted lines in the upper quadrants on the back of the astrolabe.

CCA No. 52

(FIGURES 54, 55)

Date: A.H. 1189 [1775].
Signature: See "Remarks."
Components: Backplate with throne laminated to rim with throne, handle, ring, five plates, rete,

FIGURE 54.—Astrolabe No. 52. Front view.

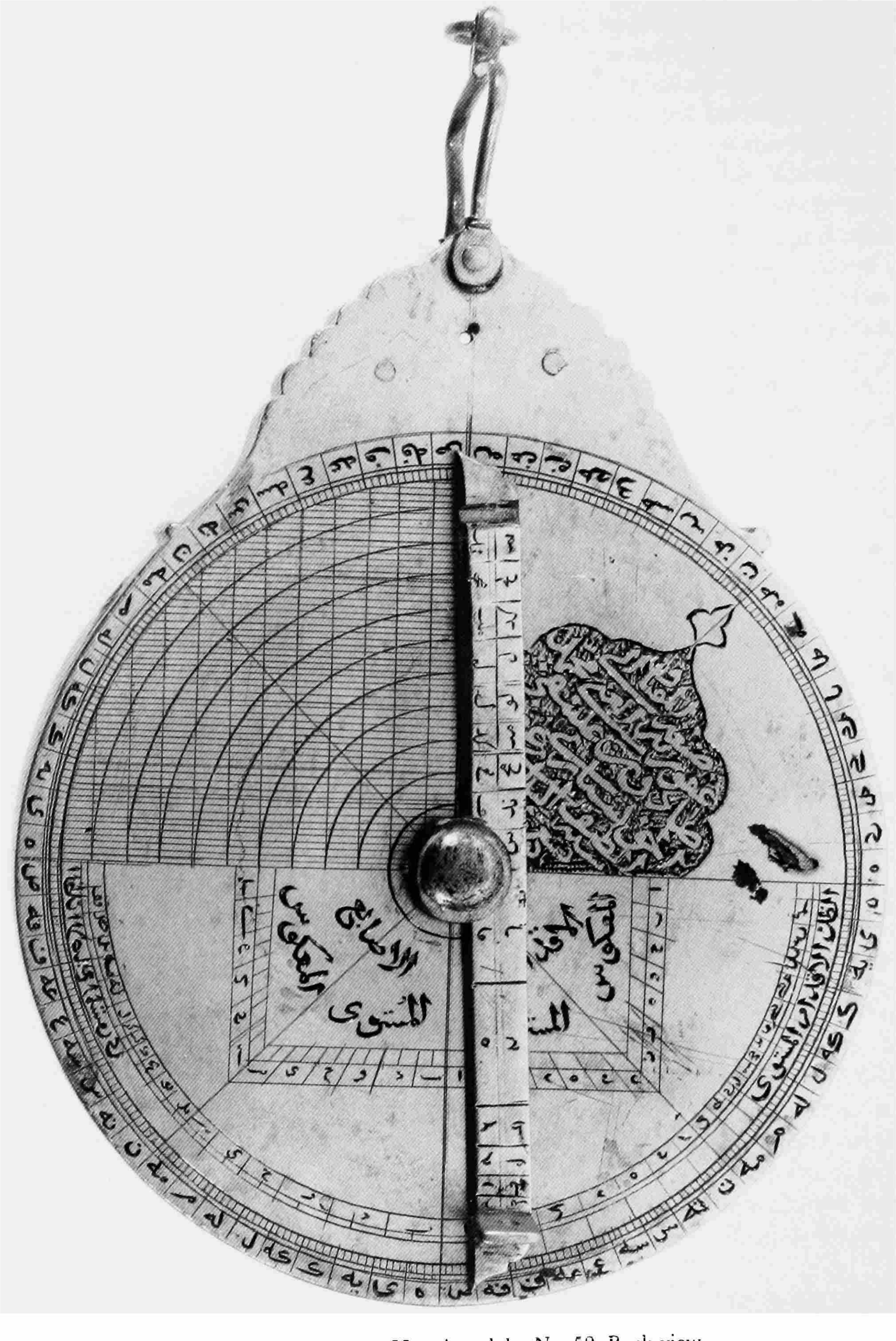


FIGURE 55.—Astrolabe No. 52. Back view.

alidade, pin, wedge, index.

Diameter: 95.5 mm.

Material: Brass.

Characteristics: The throne is broad and shaped like a Moorish arch. A shallow, circular depression (10.5 mm in diameter) decorates the front face. The handle is stirrup-shaped. It has a loop for the ring. The ring has a circular cross-section. The rim is divided into a scale of 360° with the last division marked "360" in *abdjad* numerals. The gazetteer in the front central area is arranged in spiral bands. It includes 47 place names with longitude, latitude, and Qibla azimuth for each. Two or three additional, barely legible places and parameters, including possibly *Ka*ᶜ*bah*, are inscribed in the two innermost segments of the spiral bands.

On the back of the astrolabe, an altitude scale occupies the upper margin. Cotangent scales occupy the lower margin with divisions of fingers at left and feet at right. The upper left quadrant is divided by 60 sine lines and 10 quarter circles. The upper right quadrant contains a cartouche inscribed as follows:

صنعه المفتاق (sic) الى عفو ربه الغنى محمد
صادق بن علينقى• الحق بستارى (؟) عفى عنهم
اللطيف البارى• سنة تسع وثمانين بعد الف و

Translated, it reads: "Made by the one who yearns for the forgiveness of his rich Lord Muḥammad Ṣadiq ibn ʿAlinaqi, rightness protects me—May the Gentle forgive them both, year 1189" (GS).

The shadow squares in the lower quadrants are divided into fingers on the left and feet on the right.

There are five plates, each with a notch at 270°. One plate face is inscribed with 24 quarter horizons, one for every 2° of latitude between 22° and 68°. The face also contains four declination scales. Two plate faces (5a, 5b) contain altitudes (every 6°) and azimuths (every 10°) for single latitudes. Two other plate faces (2a, 2b) contain unequal hours in addition to altitudes and azimuths. Two plate faces contain equal Italian hours in addition to unequal hours, altitudes, and azimuths. The plates are inscribed as follows:

Plate	*Latitude*		*Length of daylight*	
1b	ᶜ*arḍ*	34	*sā*ᶜ*ātuhu*	14 14
2a	ᶜ*arḍ*	30	*sā*ᶜ*ātuhu*	14
2b	ᶜ*arḍ*	39	*sā*ᶜ*ātuhu*	14 36
3a	ᶜ*arḍ*	32	*sā*ᶜ*ātuhu*	14 08
3b	ᶜ*arḍ*	33	*sā*ᶜ*ātuhu*	14 12
4a	ᶜ*arḍ*	36	*sā*ᶜ*ātuhu*	14 20
4b	ᶜ*arḍ*	37	*sā*ᶜ*ātuhu*	14 28
5a	ᶜ*arḍ*	42	*sā*ᶜ*ātuhu*	14 48
5b	ᶜ*arḍ*	45	*sā*ᶜ*ātuhu*	15

The rete of this astrolabe is a very simple design. It incorporates a complete straight equinoctial colure and a complete projected equator. An engraved chain of diamonds decorates the Capricorn circle. Engraved lines and dots decorate equator and equinoctial bar. A piece of metal connecting the ecliptic with the equator has been inscribed:

يا صادق الوعد

It translates: "O! You Who is true to the promise" (GS). The ecliptic is subdivided into units of 6°. There are 18 inscribed star pointers. Projections of colures, tropics, and equator have been engraved on the back of the rete. The alidade is not counterchanged. The one remaining sighting plate is pierced by a single hole. A sundial scale divides one arm. There are nine equal divisions on the other arm. The first division along the beveled edge is marked "6," the last, "54." The first division along the flat edge is marked "12;" the last, "60." The pin is a bolt with a flat head and a doorknob-shaped tip. The wedge is duck-shaped. The index is 83.5 mm long. Only one arm is engraved with twelve equal divisions. These are identified twice: once from center to edge from"5" to "60," and once from edge to center. The undivided arm is decorated with vines and flowers on a stippled background.

The alphabet is Arabic Naskhi. Hindu-Arabic numerals identify lines projected on the horizon plate.

Remarks: The phrasing of the inscription on the back of this astrolabe leaves open the possibility that Muḥammad Ṣadiq is its owner rather

than its maker. Saliba has observed that the inscription on the rete is a play on a portion of the maker/owner's name. The circular depression on the throne may have once held a compass. One of the Hoffman photos shows a cord attached to this instrument. It has since been removed. While there is currently no plate holder in the front central area of this astrolabe, there are indications that there was once a tooth at 270° The inscription of the front central area is of poor quality. The rete, which includes examples of good lettering, is slightly bigger than the front central area. On most plates the word "mashriq" has been written in reverse to preserve a certain symmetry near the horizon.

CCA No. 53

(FIGURES 56, 57)

Date: A.H. 1216 [1801].

Signature: ṣana^{c}ahu Ṣadiq (maker), namaq-ahu al-Ḥaqir ^{c}Abd al-Karim (decorator).

Components: Rim with throne laminated to backplate with throne, handle, seven plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 96.5 mm.

Material: Brass.

Characteristics: The high, symmetric Moorish arch is embossed with vines and flowers. It is pierced by a central teardrop-shaped hole. The handle is decorated with a high, pierced crown. The axle of the handle pierces the throne from side to side rather than from front to back. The rim is divided into four 90° arcs. Each of these arcs is subdivided into units of 6° inscribed with *abdjad* numerals. The front central area contains a gazetteer of 23 cities along with their longitude, latitude, azimuth of Qibla, and distance from Mecca (in farsakhs). In the center of the table, the phrase

كعبه مشرفه طوله عزى عرضه كام ٣٥٤ ٠٠٠

has been inscribed.

On the back of the astrolabe, the upper half of the margin contains two altitude scales. The lower half of the margin contains two cotangent scales. The upper left quadrant is divided by ten sine lines and ten cosine lines separated by equal intervals. Four arcs tangent to the first four lines of each scale intersect the sines and cosines. Semicircles have been engraved on the radii of this quadrant. The upper right quadrant contains a lengthy inscription embossed on a stippled background.

شرلاف (sic) سلالة السادات ابن محمد نصير

عبد الله الرضوى • صنعه صادق

It translates: "The astrolabe of the descendant of Sayyids ibn Muḥammad Naṣir ^{c}Abd $^{\supset}$Allah ^{c}Al-Riḍawi, made by Ṣadiq" (GS).

The lower quadrants contain shadow squares divided into fingers on the left and feet on the right. The inscription inside the shadow squares reads:

نمقه الحقير عبد الكريم ١٢١٦

It translates: "Decorated by the wretched ^{c}Abd al-Karim 1216" (GS).

Each of the seven plates is notched at 270°. One plate face contains 37 stereographically projected semi-horizons, one for every 2° between and including 22° and 90°. There are traces of unfinished obliquity scales on this face. The other plate faces all contain stereographically projected horizons, altitudes (every 6°), azimuths (every 30°), and unequal hours. One plate face (for latitude 31°) contains a stereographically projected scale of equal Italian hours as well as the unequal hour scale. The plate faces are inscribed with the following latitudes and lengths of daylight:

Face	*Latitude*		*Length of daylight*	
1b	*li-^{c}arḍ*	42	*sā^{c}ātuhu*	14 40
2a	*li-^{c}arḍ*	22	*sā^{c}ātuhu*	12 ?
2b	*^{c}arḍ*	33	*sā^{c}ātuhu*	14 12
3a	*^{c}arḍ*	30	*sā^{c}ātuhu*	14 00
3b	*^{c}arḍ*	48	*sā^{c}ātuhu*	16 00
4a	*^{c}arḍ*	34	*sā^{c}ātuhu*	14 16
4b	*^{c}arḍ*	31 (?)	*sā^{c}ātuhu*	14 16 (?)
5a	*^{c}arḍ*	35	*sā^{c}ātuhu*	14 20
5b	*^{c}arḍ*	37	*sā^{c}ātuhu*	14 28
6a	*^{c}arḍ*	36	*sā^{c}ātuhu*	14 24
6b	*^{c}arḍ*	66	*sā^{c}ātuhu*	24 00
7a	*^{c}arḍ*	38	*sā^{c}ātuhu*	14 32
7b	*^{c}arḍ*	39	*sā^{c}ātuhu*	14 36

The rete design includes a counterchanged

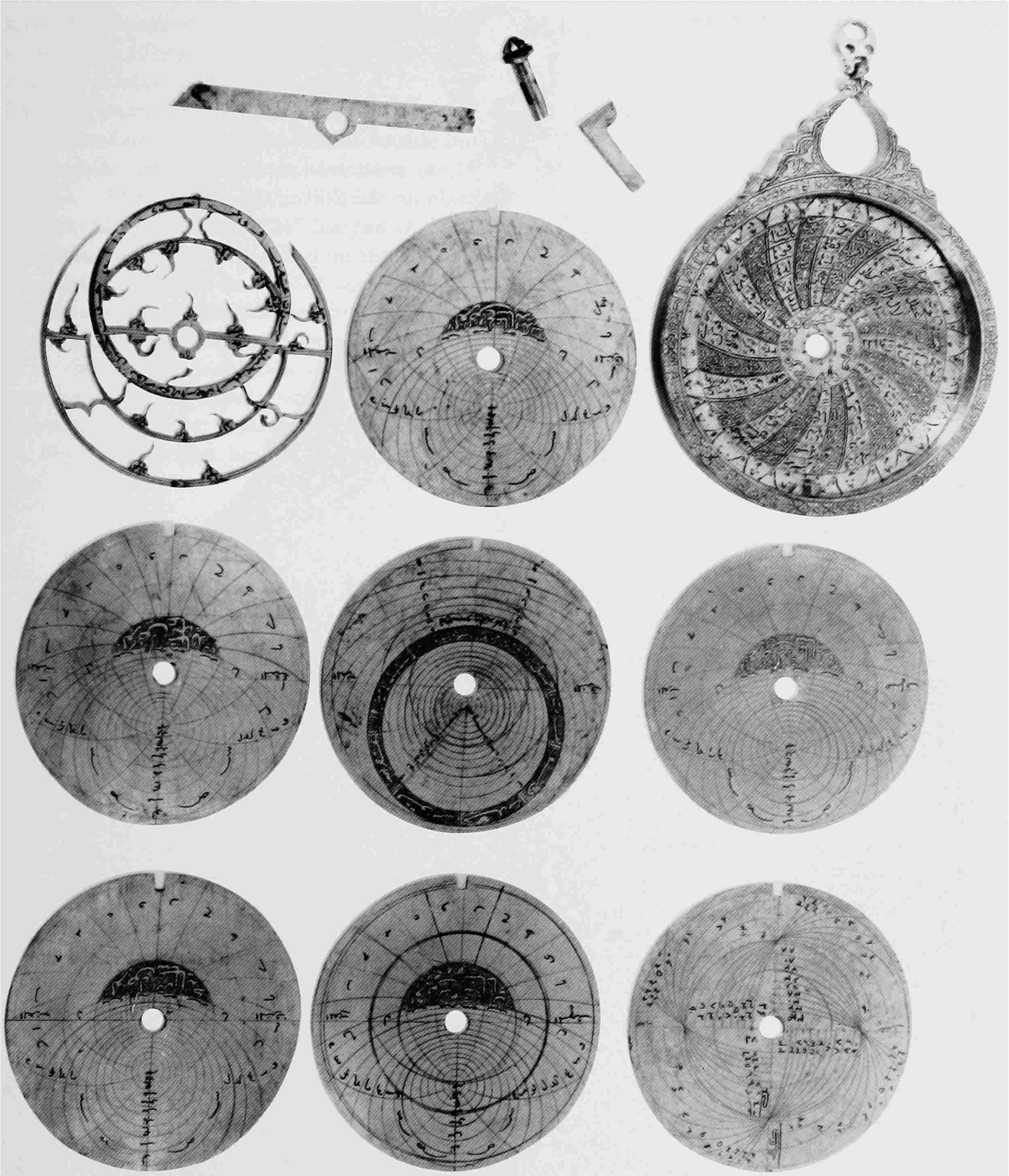


FIGURE 56.—Astrolabe No. 53. Front view of separate parts.

equinoctial colure and a complete equator. The 24 star pointers are bi-lobed flames. The ecliptic is subdivided into 60 units of 6° each. Engraved lines on the back of the rete include equator and Capricorn circles and ecliptic divisions. The straight alidade contains a sundial scale on one side and the equal divisions of a sexagesimal scale on the other arm. Each sighting plate is pierced

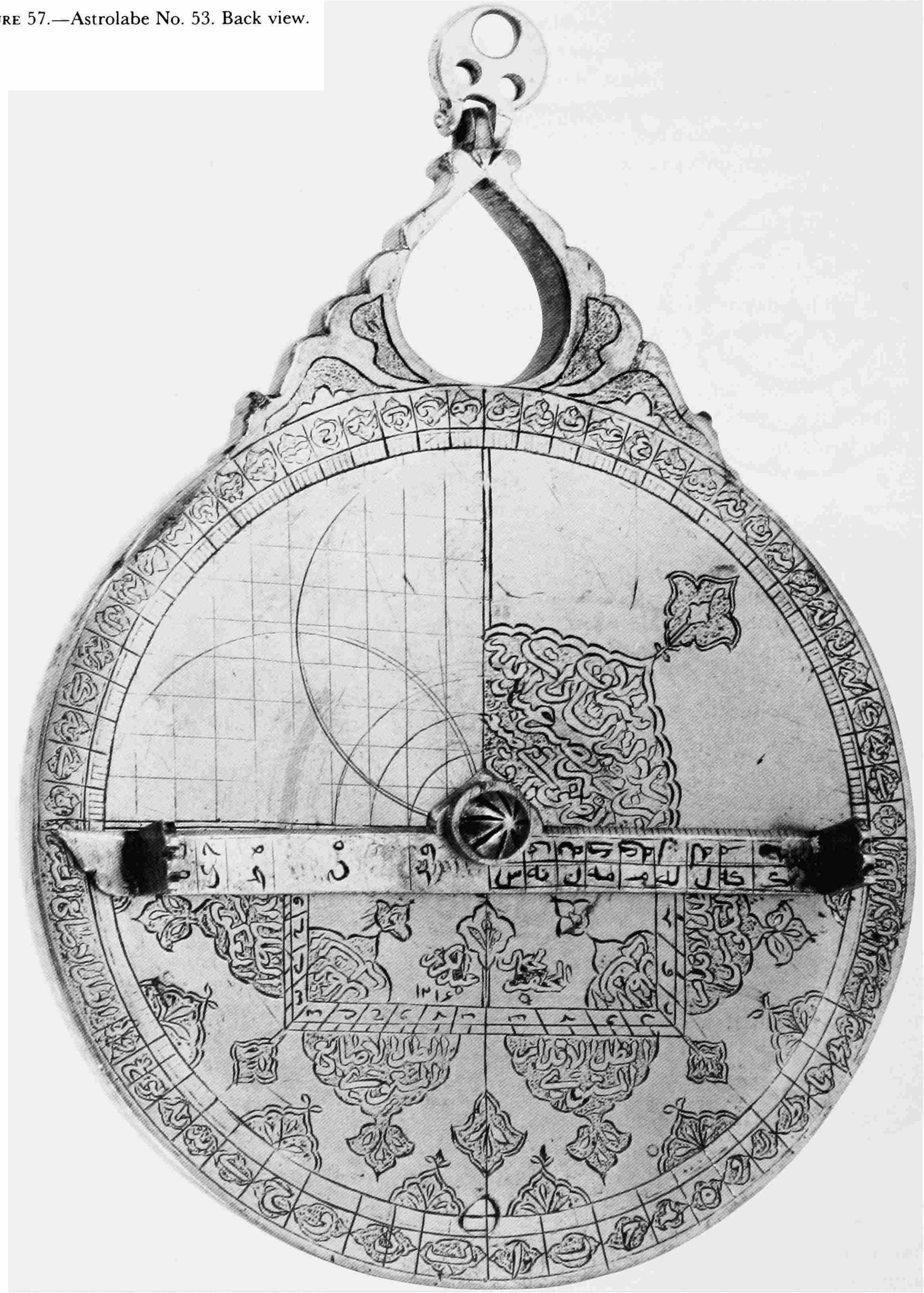


FIGURE 57.—Astrolabe No. 53. Back view.

with two holes, one above the other. The pin is a bolt with conical head. The ringlet is a flat circle. The wedge is boot-shaped.

The inscription is in Arabic Naskhi. Except on the horizon plate, where some Hindu-Arabic numerals appear, *abdjad* numerals have been used.

Remarks: The reading of the latitude on plate 4b is uncertain; it may be "34" instead of "31." The reading of the hours marked on this plate is also uncertain. It could be "14 04" instead of "14 16." Construction guidelines are visible on many of the plates. Some engraved lines are double. Two of the scales on the rim of this astrolabe (upper left and lower right) measure altitude; the remaining two scales measure zenith distance. CCA No. 52 has also been attributed to this maker.

CCA No. 54

(FIGURES 58, 59)

Date: A.H. 1196 [1781] (GS).

Signature: None.

Components: Body with throne, handle, five plates, rete, pin, and wedge.

Diameter: 98.5 mm.

Material: Brass.

Characteristics: The delicately pierced throne is decorated on the front and back with vines and flowers embossed on a stippled background. In addition, an inscription on the front of the throne reads:

هو الغفور • يا علام الغيوب

It translates: "He is the forgiver, O knower of mysteries" (GS). The date is inscribed on the back of the throne as follows:

في سنة ١١٩٦

The handle is itself a high, pierced Moorish arch attached to a horizontal axis. The rim is inscribed with four contiguous scales of 90°, each proceeding in a clockwise direction. A blank gazetteer grid fills the front central area. There is a tooth at 270°.

On the back of the astrolabe, the upper margin contains two altitude scales. The lower margin contains cotangent scales divided into feet (left) and fingers (right). Two arcs of a stereographically projected declination scale have been engraved in the upper right quadrant. The upper left quadrant contains sines for every five degrees and arcs marking the unequal hours. There are shadow squares in the lower quadrants divided into feet (left) and fingers (right). A quotation from the Koran, Chapter VI, Verse 59, is engraved along the outer edge:

وعنده مفاتيح الغيب لا يعلمها الا هو •
ويعلم ما فى البر و البحر وما تسقط من
ورقة الآ ويعلمها ولا حبة فى ظلمات الارض
ولا يابس الآ فى كتاب مبين

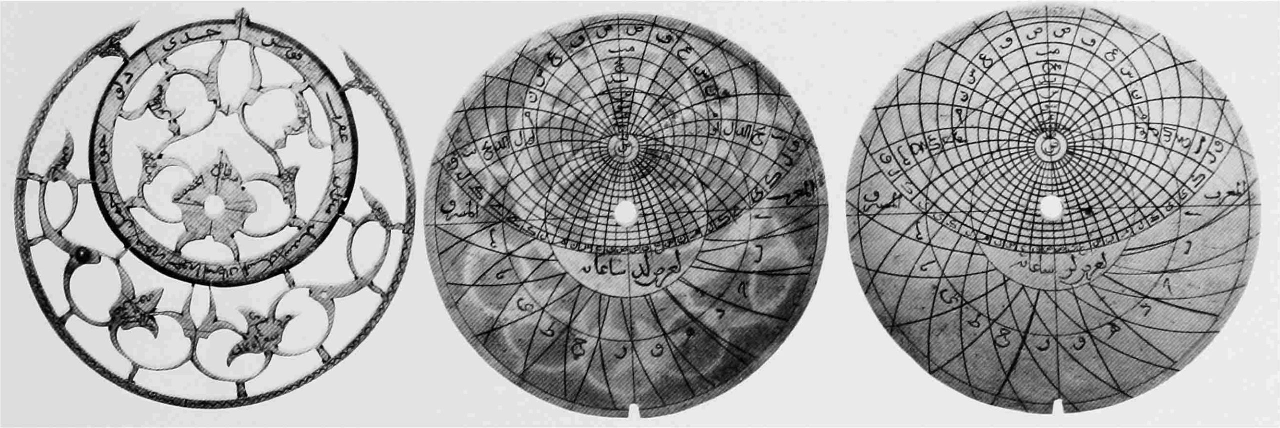


FIGURE 58.—Astrolabe No. 54. ʿ*Ankabūt* (left) and plates for latitudes 34° and 37°

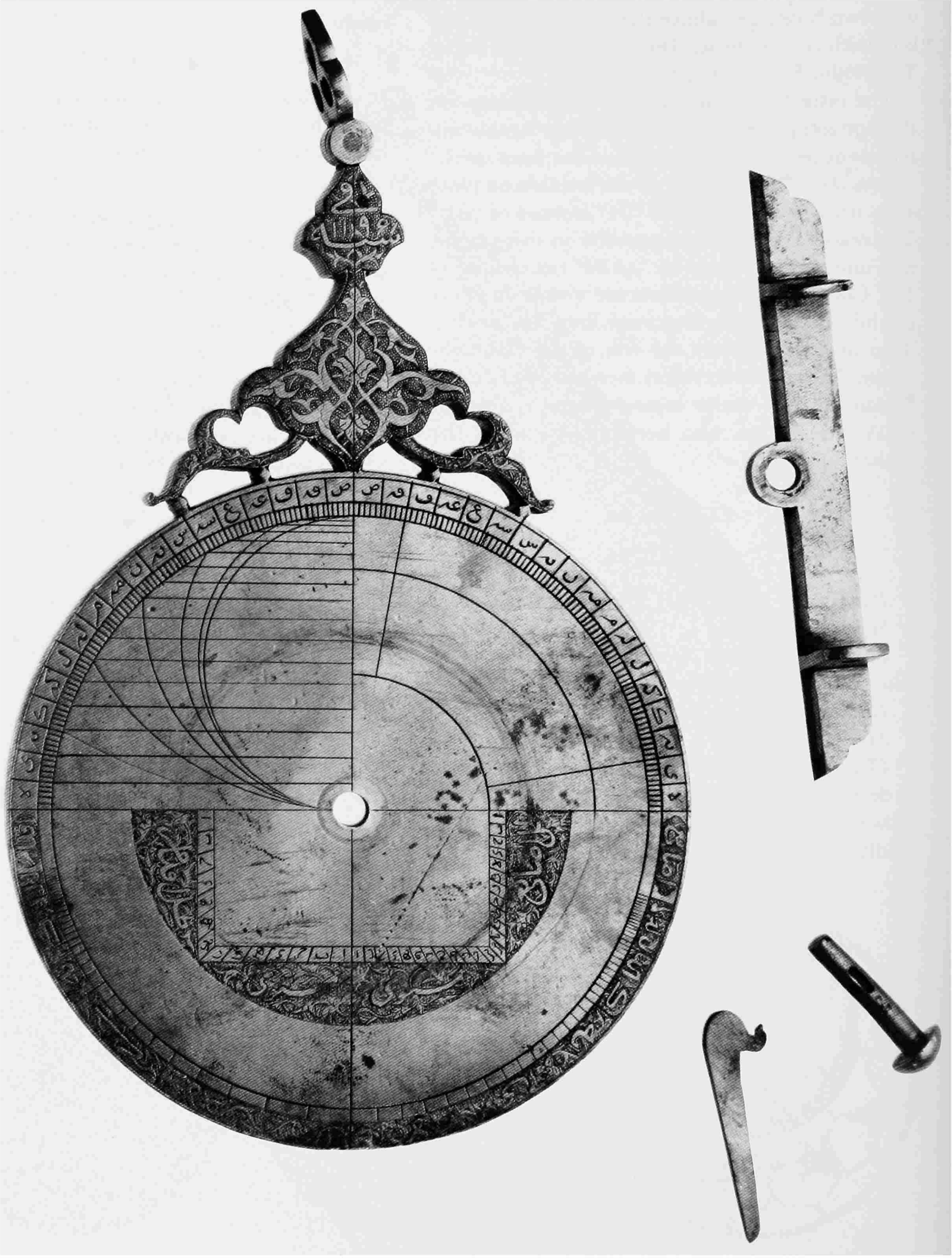


FIGURE 59.—Astrolabe No. 54. Back view.

The verse translates as follows: "And with Him are the keys to the unseen—none knows them but He; and He knows what is in the land and the sea; and there falls not a leaf but he knows it, nor a grain in the darkness of the earth, nor anything green or dry but [it is all] in a clear book."

This astrolabe has five plates. Each is notched at 270°. One plate face contains eighteen semi-horizons representing every 3° of latitude between 12° and 63°, as well as one complete horizon for 66°. Eight plate faces contain stereographically projected coordinates for single latitudes, including altitudes (every 6°), azimuths (every 10°), unequal hours, and equal Italian hours. One plate face (4b) contains, in addition to the coordinates engraved on the other faces, a set of equal Babylonian hours. On all single-latitude faces, the latitude is inscribed accompanied by the word *sā^{c}ātuhu*. However, no hours are given. The latitudes are:

Plate	*Latitude*
1b	*li-^{c}arḍ* 34
2a	*li-^{c}arḍ* 29
2b	*li-^{c}arḍ* 35
3a	*li-^{c}arḍ* 32
3b	*li-^{c}arḍ* 33
4a	*li-^{c}arḍ* 36
4b	*li-^{c}arḍ* 39
5a	*li-^{c}arḍ* 37
5b	*li-^{c}arḍ* 38

The rete pattern is remarkably symmetric. It is formed by curling vines and incorporates 13 named stars. The ecliptic is subdivided into units of 6°. The Capricorn circle is decorated with an engraved chain. On the front of the rete there are traces of engraved colures and equator and Cancer circles. On the back of the rete there are traces of colures, equator circle, and arc divisions of the equator. The alidade is not counterchanged. There are crude equal divisions along the beveled edge of one arm. The sighting plates are pierced with two holes above the fiducial line. The upper hole is larger. The pin is a tapered bolt with a hemispherical head. The wedge is shaped like a duck.

The inscription is Arabic Naskhi.

Remarks: The attribution of this astrolabe to ^{c}Abd al-Ghafur by Gunther was apparently based on the obvious similarity between its rete and the rete of an astrolabe signed by that maker (see No. 55). There are several indications that this is an unfinished work: there are no entries in the gazetteer; the declination scale is incomplete; no hours of daylight have been engraved on the plates. In designing the rete this maker has selected stars that preserve symmetry. All are correctly positioned. ^{c}Abd al-Ghafur projects these same stars on his instrument.

CCA No. 55

(FIGURES 60, 61)

Date: A.H. 1198 [1783].

Signature: ^{c}amal ^{c}Abd al-Ghafur.

Components: Body with throne, handle, five plates, rete, alidade, pin, wedge, and index arm.

Diameter: 133.5 mm.

Material: Brass.

Characteristics: The throne is a high Moorish arch, decorated with vines and flowers embossed on a stippled background. There is inscription on front and back. The inscription on the front reads:

يا علام الغيوب • ولا يحيطون بشيء من
علمه الا بما شاء • وسع كرسيه السموات
والارض •

and can be translated, "O knower of mysteries, they encompass nothing of His knowledge save what He will. His throne holds the heavens and the earth" (GS). The inscription on the back gives the date of the instrument. The handle is basically stirrup-shaped, but it has a high, pierced crown. The rim is divided by four contiguous scales of 90°, each proceeding in a clockwise direction. There is a tooth in the front central area at 270°. In addition, a gazetteer has been inscribed there. It lists 46 places along with the longitude, latitude, and azimuth of Qibla for each.

On the back of the astrolabe, the upper margin is divided by altitude scales. The lower margin contains cotangent scales divided into feet (left) and fingers (right). In the upper right quadrant

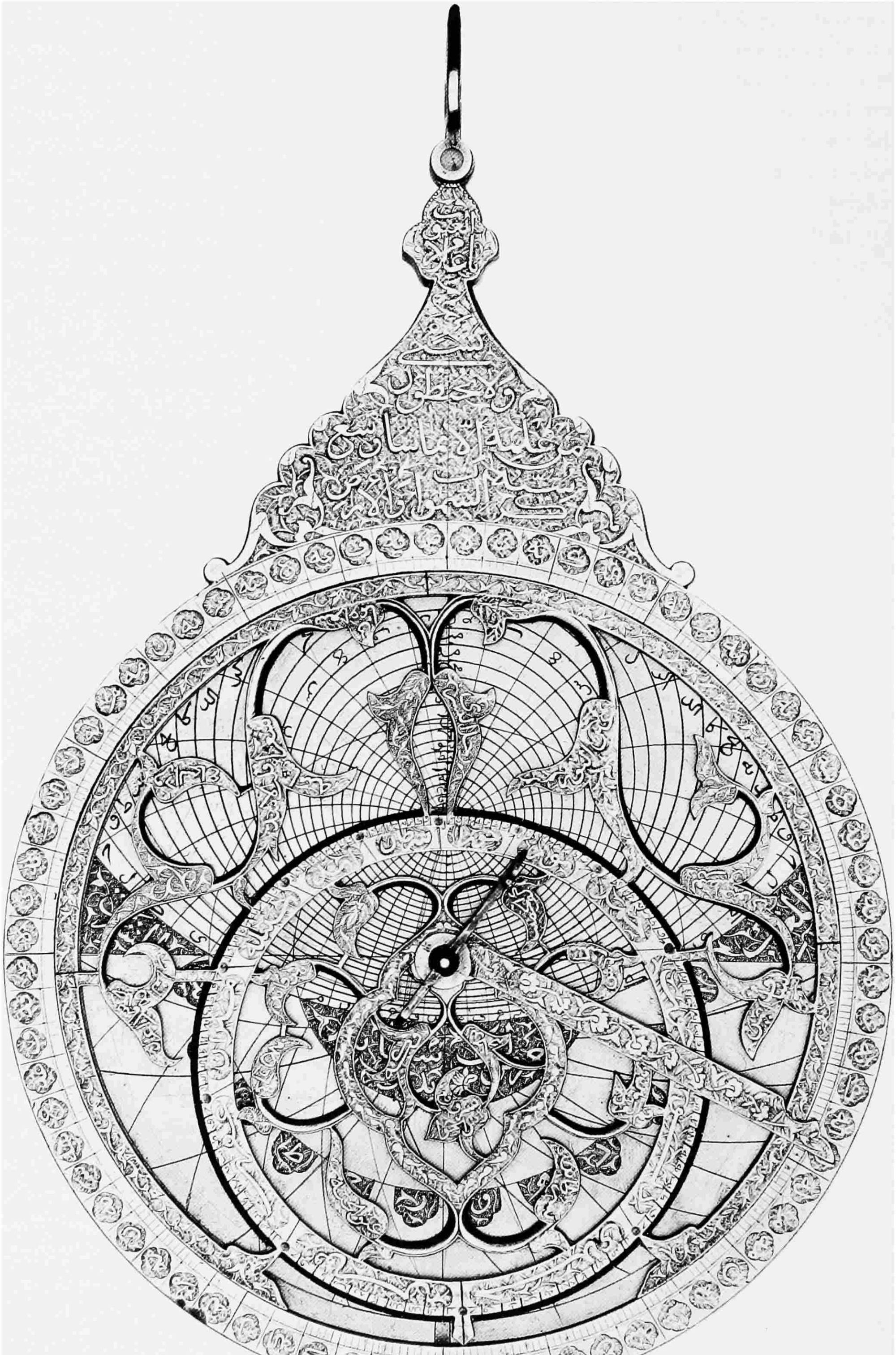


FIGURE 60.—Astrolabe No. 55. Front view.

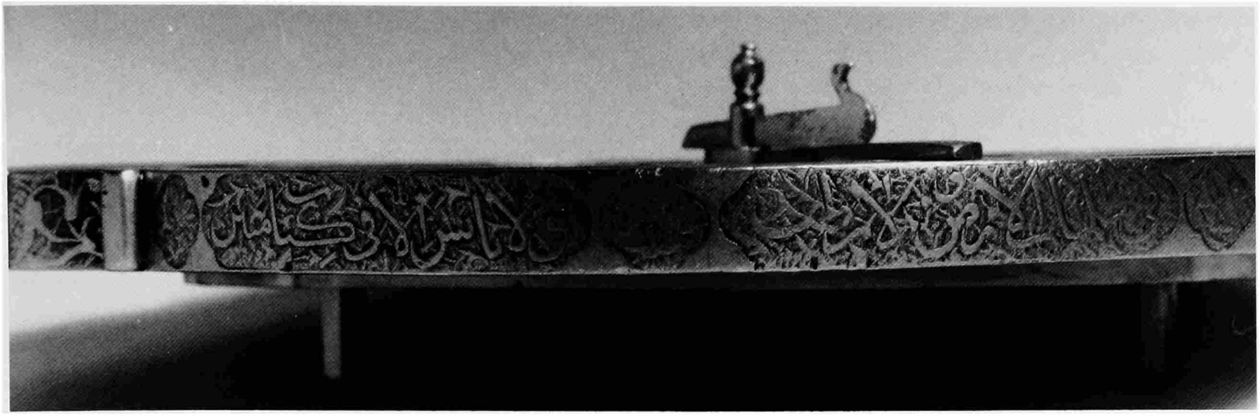


FIGURE 61.—Astrolabe No. 55. Inscribed edge.

there is a stereographically projected declination scale. For a transcription and translation of the inscription outside the outermost declination arc, see this catalog, CCA No. 59. In the upper left quadrant there are sine lines for every five degrees. The unequal hours are also engraved in this quadrant, identified with the phrases:

خطوط ساعات معوج

which translates, "Lines of unequal hours" (GS). There are shadow squares in the lower quadrants, divided into feet (left) and fingers (right). A scale of triplicities has been engraved inside the squares. Its title is transcribed and translated in the description of CCA No. 37. The natures are identified using Persian terms. Outside the squares there are semicircular lists of planetary governors of terms, terms, zodiacal signs, planetary governors of faces, and lunar mansions. The signature fills a cartouche below the shadow squares. On the outside edge of the body of this instrument, there is an inscription which reads:

اعوذ بالله من الشيطان الرجيم • وعنده
مفاتيح الغيب لا يعلمها الا هو ويعلم ما فى
البر و البحر وما تسقط من ورقة الا يعلمها
ولا حبة فى ظلمات الارض ولا رطب ولا يابس الا
فى كتاب مبين •

Translated, it is: "I take refuge in God from the devil," followed by Chapter VI, verse 59 of the Koran (see p. 95).

This astrolabe has five plates. Each of these has a notch at 270°. Nineteen semi-horizons have been engraved on one plate face; there is a horizon for every 3° of latitude from 12° to 66°. On this same face there are four scales useful for measuring declination. All other faces contain stereographically projected coordinates appropriate for a single latitude. The coordinates include altitudes (every 3°), azimuths (every 10°), unequal hours, and equal Italian hours. The faces are inscribed as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ʿarḍ* 32	*sāʿātuhu* 14 06
2a	*ʿarḍ* 29	*sāʿātuhu* 13 14
2b	*ˋarḍ* 40	*sāʿātuhu* 14 51
3a	*ʿarḍ* 33	*sāʿātuhu* 14 12
3b	*ʿarḍ* 35	*sāʿātuhu* 14 22
4a	*ʿarḍ* 34	*sāʿātuhu* 14 17
4b	*ʿarḍ* 36	*sāʿātuhu* 14 28
5a	*ʿarḍ* 37	*sāʿātuhu* 14 37
5b	*ʿarḍ* 38	*sāʿātuhu* 14 43

The rete of this astrolabe exhibits remarkable symmetry. It is composed of curling vines, some of which form a Moorish arch inside the ecliptic. The arch is decorated with an embossed chain of leaves, as is the Capricorn circle. The ecliptic is subdivided into units of 3°. There are 22 inscribed star pointers. No construction guidelines are visible either on the front or on the back of the rete. The alidade is counterchanged about the center. There is no decoration, but each arm is divided into 60 equal units. The sighting plates are each

pierced with two holes, a larger hole above a smaller one. The pin is a bolt with hemispherical head and doorknob-shaped tip. The wedge is shaped like a duck. This astrolabe is also fitted with a radial index arm decorated with embossed vines and flowers on a stippled background.

The inscription is in Arabic Naskhi.

Remarks: There is some evidence on the back of this carefully constructed astrolabe that the maker was interrupted in his work. The lengthy inscription in the upper right quadrant refers to lines marking the altitude of the noon sun at various latitudes, but the lines themselves have not been drawn.

One other astrolabe bearing ᶜAbd al-Ghafur's signature is in the Hermitage Museum, Leningrad, CCA No. 3669.

CCA No. 57

(FIGURES 62, 63)

Date: A.H. 1202 [1787].
Signature: None.
Components: Body with throne, handle, ring, seven plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 89 mm.
Material: Brass.

Characteristics: The uninscribed, undecorated, and unpierced throne is shaped like a scalloped triangle. The stirrup-shaped handle has a diamond cross-section, as does the ring. The rim is divided by a scale of 360°. The last division is marked 60 in *abdjad* numerals. There is a gazetteer in the front central area which lists 30 places and gives for each the longitude, latitude, and azimuth of the Qibla.

On the back of the astrolabe the upper margin contains altitude scales. The lower margin contains cotangent scales divided into fingers (left) and feet (right). The upper right quadrant contains a rectangular multiple difference table entitled:

فضل الدور

آحاد السنين وعشرات السنين

which translates "Excess of Revolution / single years and tens of years" (GS).

This quadrant also contains the following in-

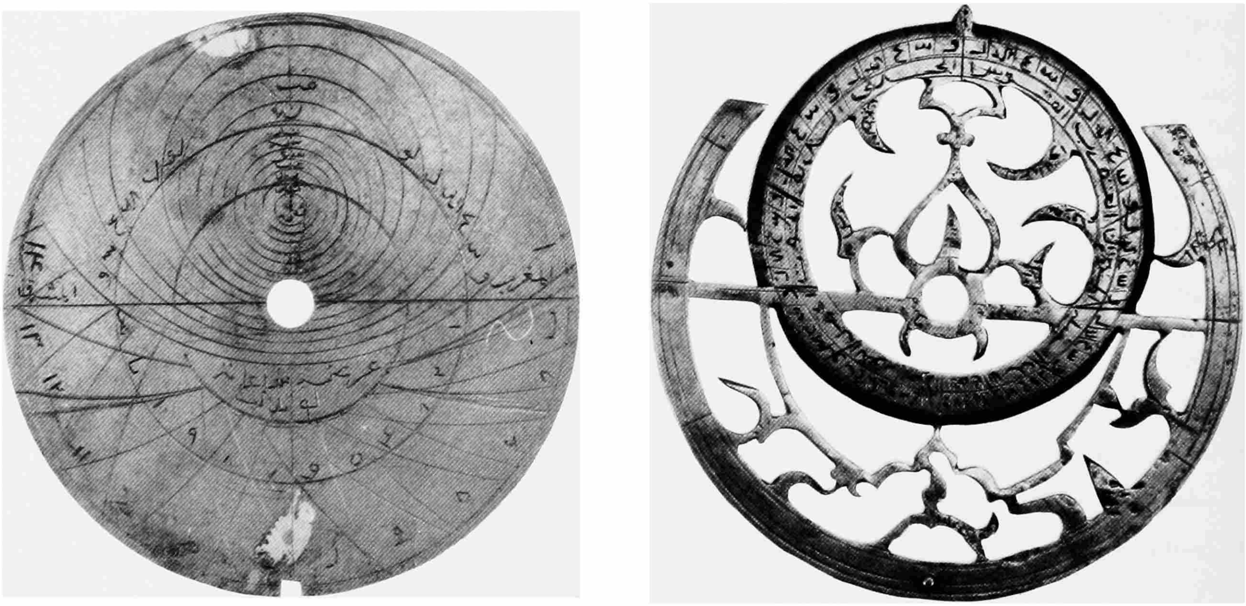


FIGURE 62.—Astrolabe No. 57. ᶜ*Ankabūt* (right) with plate for 36°

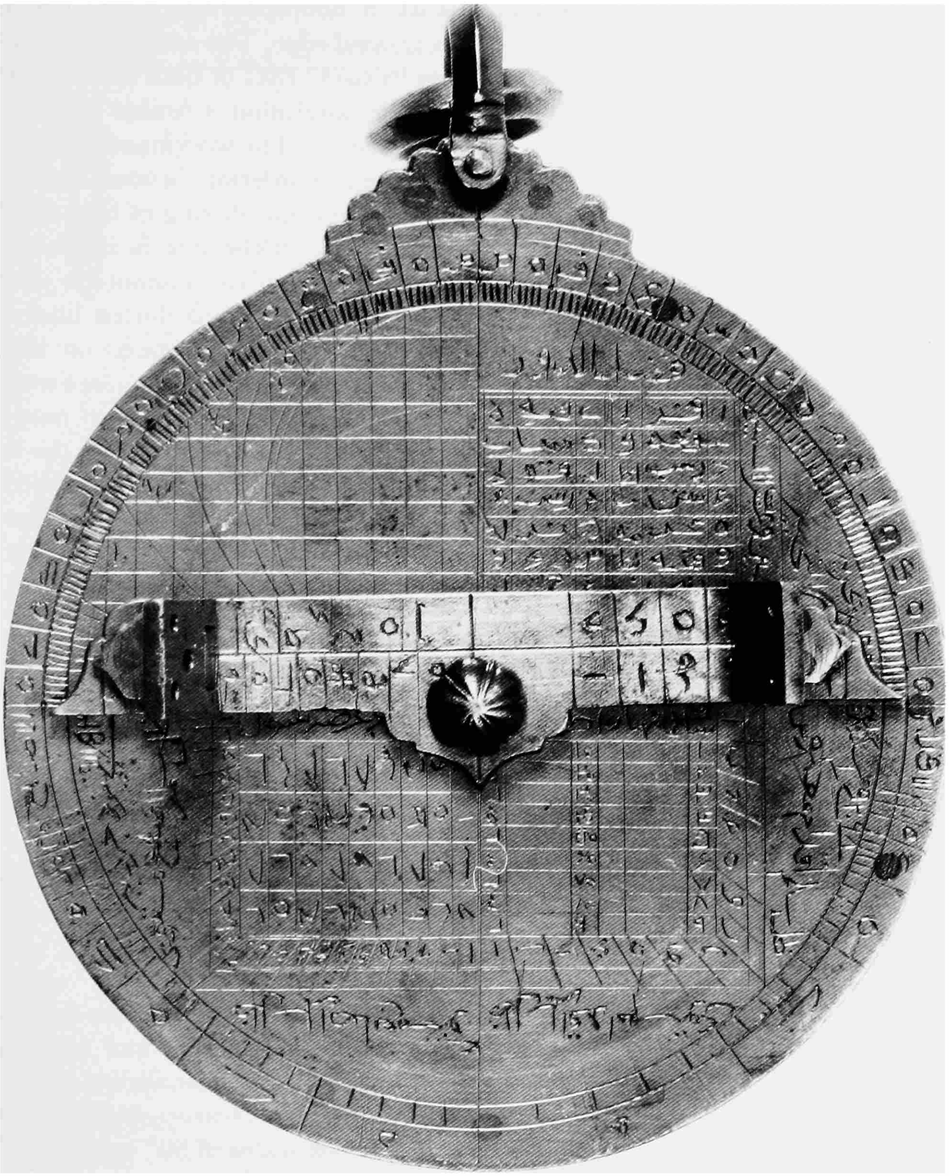


FIGURE 63.—Astrolabe No. 57. Back view.

scription:

١٢٠٢ سنة هجرية عليه السلام و التحية

which can be translated: "In the year 1202 of the Hejira may God's peace and salutations be upon him [the Prophet]" (GS). Twelve equally spaced sines and an equal number of cosines divide the upper left quadrant. Six arcs representing the unequal hours are graphed on this grid. Shadow squares divided into fingers (left) and feet (right) occupy the lower quadrants. Inside the shadow squares there is an untitled table of triplicities and a table of factors surmounted by the following inscription:

ساعات نهار اطول كد د عرضه سو ل

Translated, it reads "66° 30′ latitude, longest day 24 hours." The lower left quadrant contains the date "1153 *Yazdijirdii.*"

١١٥٣ يزدجردية

The lower right quadrant contains the date "2098 *Alexandrii.*"

٢٠٩٨ اسكندرية

The astrolabe is fitted with seven plates, each notched at 270°. The faces of one plate contain only straight lines and circles. Five faces (1a, 1b, 3a, 4a, 6a) contain a stereographically projected reference frame for a single latitude consisting of horizon, altitudes (every 6°), and unequal hours. One face (3b) contains a reference frame that consists of horizon, altitudes (every 6°), azimuths (every 10°), and unequal hours. Six faces (2a, 2b, 4b, 5a, 5b, 6b) contain a reference frame consisting of horizon, altitudes (every 6°), unequal hours, and equal Italian hours. All faces containing the reference frame are engraved as follows:

Plate	*Latitude*		*Length of Daylight*	
1a	ᶜ*arḍ*	26		
1b	ᶜ*arḍ*	22	*sāᶜātuhu*	13 21
2a	ᶜ*arḍ*	29	*sāᶜātuhu*	13 52
2b	ᶜ*arḍ*	27		34
3a	ᶜ*arḍ*	34	*sāᶜātuhu*	14 17
3b	ᶜ*arḍ*	30	*sāᶜātuhu*	13 57
4a	ᶜ*arḍ*	36	*sāᶜātuhu*	14 30
4b	ᶜ*arḍ*	37	*sāᶜātuhu*	36 14
5a	ᶜ*arḍ*	34	*sāᶜātuhu*	14 17
5b	ᶜ*arḍ*	36	*sāᶜātuhu*	14 22
6a	ᶜ*arḍ*	40	*sāᶜātuhu*	14 52
6b	ᶜ*arḍ*	19 (?)	*sāᶜātuhu*	15

The rete exhibits a certain symmetry. In addition to vines and leaves it also includes a straight equinoctial bar and the lower portion of the celestial equator. There are only nine inscribed and one uninscribed star pointers. The ecliptic band is subdivided into units of 6°. The alidade is not counterchanged. There are six equal divisions (representing declination arcs) visible on one arm. On the other arm there are eight equally spaced divisons corresponding with the sine scale and at least three sundial divisions. Each collapsible sighting plate is pierced with three holes, none above the fiducial line. The pin is a cylinder with a hemispherical head. The ringlet has a scalloped edge. The wedge is a horse with a duck on its back. Eyes of both are drilled.

The inscription is Arabic Naskhi.

Remarks: The workmanship evident in this instrument is inferior. Several corrections in positioning and numbering of lines can be seen. The inscription on the rete is in an amateur hand. The sighting plates cannot be used accurately. The maker has used dotted lines to emphasize portions of the projections on the plates. The tables inside the shadow square and in the upper right quadrant compare with ones inscribed on No. 2569. It looks as though the maker of this astrolabe intended to include the contents of the upper right quadrant in the shadow squares. For some reason he changed his mind and shifted them to their present position.

CCA No. 58

(FIGURES 64, 65, 66)

Date: A.H. 1234 [1818].

Signature: ṣanaᶜahu Muḥammad Akbar.

Components: Rim with throne attached to backplate with throne, handle, ring, six plates, rete, alidade, pin, ringlet, and wedge.

Diameter: 222 mm.

Material: Brass.

Characteristics: The throne is a broad Moorish arch, decorated (front and back) with an embossed dedicatory inscription.

The handle is stirrup-shaped. The ring is quite thick. Four scales of 90° have been engraved on the rim. Two of these originate at 0° and two at 180° There is a tooth projecting into the front central area at 270°. Inscribed on the front central area is a gazetteer that lists 70 places along with their longitude, latitude, and azimuth of the Qibla.

On the back of the astrolabe there are altitude scales in the upper margin. In the lower margin there are cotangent scales divided into feet (left) and fingers (right). The divisions and inscription of the cotangent scale interrupt a band of engraved vines with leaves. The upper right quad-

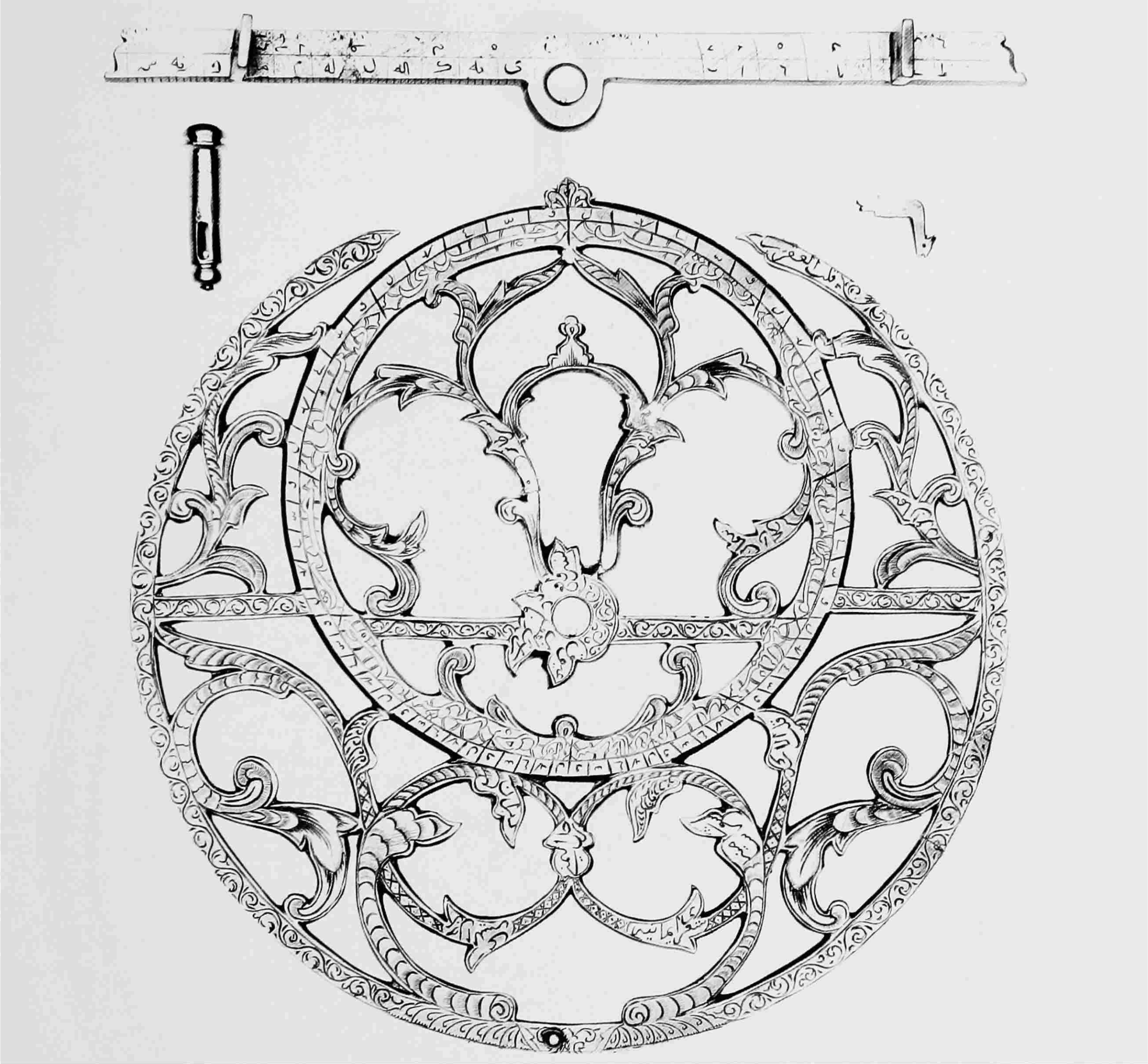


FIGURE 64.—Astrolabe No. 58. *ʿAnkabūt* and alidade.

rant contains a stereographically projected declination scale. Four lines marking the azimuth of the Qibla have been engraved on these declination arcs. They are marked Shiraz (bottom), Baghdad, Iṣfahan, Shustar. For a transcription and translation of the inscription relating to this scale, see CCA No. 49. There are also eight lines marking the altitude of the noon such for latitudes between 28° and 42°. For a transcription and translation of the inscription relating to this scale, see No. 59. In the upper left quadrant there are sines and cosines at sexagesimal intervals, as well as radii every 5°. There are shadow squares in the lower quadrants. These squares contain a scale of triplicities. The natures are identified using a combination of Arabic and Persian terms. Signature and date are inscribed in a cartouche below the shadow square. Five semicircular astrological scales occupy the lower quadrants between the shadow squares and the margin. These

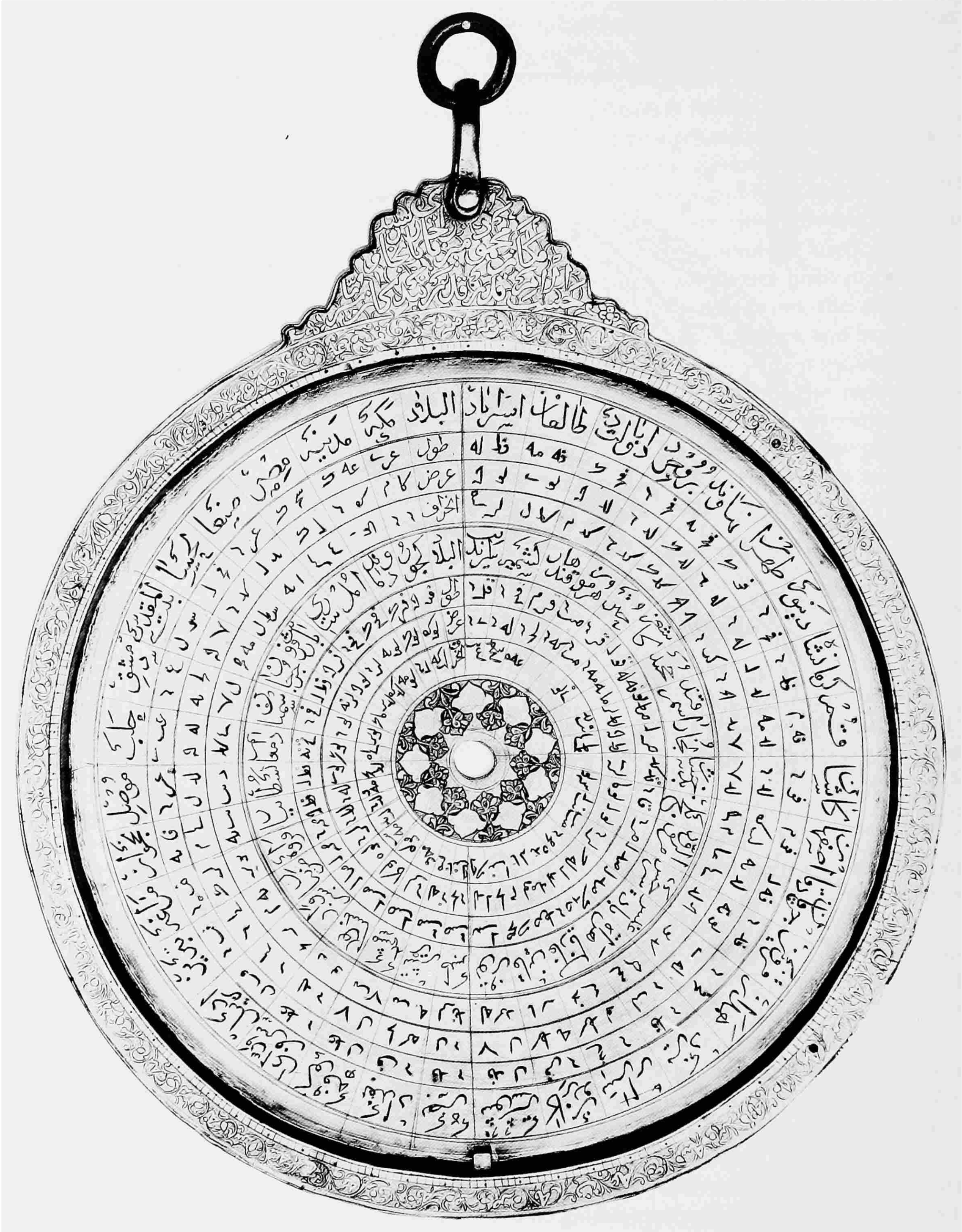


FIGURE 65.—Astrolabe No. 58. Gazetteer.

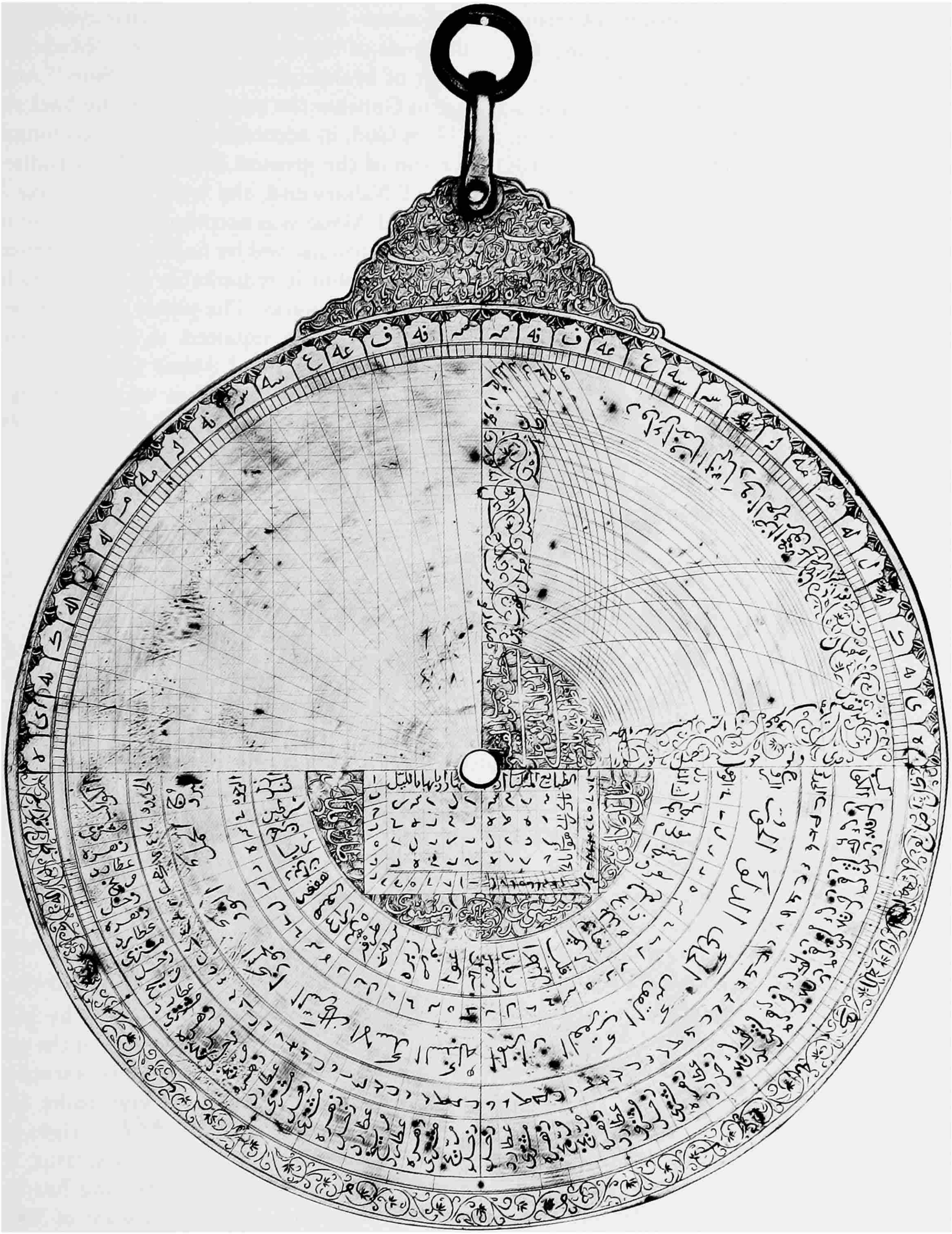


FIGURE 66.—Astrolabe No. 58. Back view.

include a scale of planetary governors of terms, degree term divisions, zodiacal signs, planetary governors of faces, and lunar mansions.

The astrolabe is fitted with six plates. Each of these has a notch at 270°. One plate is blank on one face except for three stereographically projected circles; the other face is divided into squares. A second plate has 19 quarter-horizons and four declination scales engraved on one face. The other face of the second plate contains stereographically projected coordinates for a single latitude. These include altitudes (every 2°), azimuths (every 10°), unequal hours, equal Italian hours, and equal Babylonian hours. Two plate faces (4b and 6b) contain these coordinates except for the equal Babylonian hours. Six plate faces contain only altitudes, azimuths, and unequal hours. The plate faces are inscribed with latitudes as follows:

Plate	*Latitude*	*Length of Daylight*
2b	*li-ᶜarḍ* 38	*al-sāᶜāt* 14 40
3a	*li-ᶜarḍ* 22	*al-sāᶜāt* 13 21
3b	*li-ᶜarḍ* 35	*al-sāᶜāt* 14 20
4a	*li-ᶜarḍ* 29	*al-sāᶜāt* 13 52
4b	*li-ᶜarḍ* 36	*al-sāᶜāt* 14 28
5a	*li-ᶜarḍ* 37	*al-sāᶜāt* 14 34
5b	*li-ᶜarḍ* 43	*al-sāᶜāt* 15 54
6a	*li-ᶜarḍ* 34	*al-sāᶜāt* 14 17
6b	*li-ᶜarḍ* 30	*al-sāᶜāt* 13 57

The rete is quite symmetrical. It includes a counterchanged equinoctial colure as well as thick twining vines. The ecliptic circle is subdivided into units of 6°. An engraved vine decorates both Capricorn circle and equinoctial bar. There are 13 inscribed star pointers. The alidade has no counterchanges. Six stereographically projected declination arcs have been inscribed on one arm. The other arm is divided into 12 equal units along the beveled edge. There are five unequal divisions along the top. Each sighting plate is pierced with two holes; the upper is larger. The pin is a bolt with a doorknob-shaped tip. The ringlet is ocatagonal. The wedge is shaped like a duck.

The alphabet employed by this maker is Arabic Naskhi, with Hindu-Arabic numerals designating the unequal hours on the plates.

Remarks: Gunther translates the inscription on the front of the throne as follows: "Made by the order of Mahmud Mirza Kajary Said." According to Gunther the inscription on the back reads: "He is God, in accordance with the command of the son of the greatest Shah in the paradise-like city of Naharwand, the work of this slave Muḥammad Akbar was accomplished." These readings are unconfirmed by Saliba. The gazetteer of this instrument is remarkable in that it includes all diacritical marks. The plates are quite heavy. The rete is much repaired. A second astrolabe signed by Muḥammad Akbar (dated A.H. 1236) is in the Whipple Museum of the History of Science, Cambridge, England, CCA No. 1006.

CCA No. 59

(FIGURES 67, 68)

Date: A.H. 1268 [1851].
Signature: ṣanaᶜahu Ḥamza.
Components: Body with throne, handle, ring, four plates, rete, alidade, pin, ringlet, and wedge.
Diameter: 90 mm.
Material: Brass.
Characteristics: The throne is a simple Moorish arch inscribed (beginning on the back and continuing to the front):

وقفه الحمزه على من هو فى دار الاحسان
من اهل العلم ولا ينقل الا للحاجة باذن
المدرس وتوليته بيده • لعلّى واياهم
على هدى • ١٢٦٨

The inscription translates: "Donated by Ḥamza to whomever is in the charity house of the people of learning and not to be removed except with the permission of the teacher and under his supervision. May I be with them on the right path" (GS). The handle is shaped like a stirrup; it has a rectangular cross-section. The ring has a diamond cross-section. There is a scale of 360° on the rim. It is divided into 15° units, the first of these being marked "5 15" (in *abdjad* numbers) and the last "360." There is a tooth projecting from the rim at 270° A gazetteer has been en-

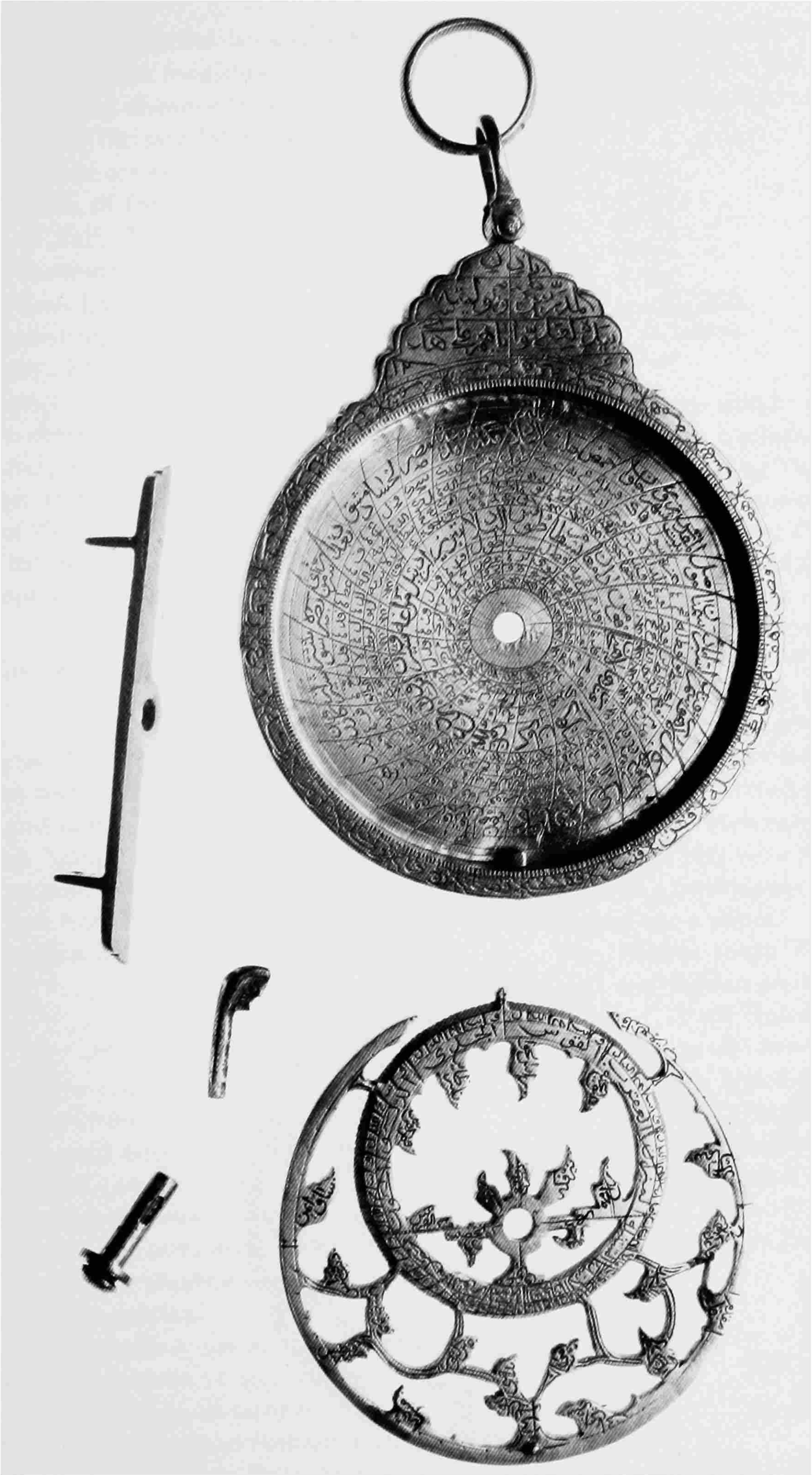


FIGURE 67.—Astrolabe No. 59. ᶜ*Ankabūt* and gazetteer.

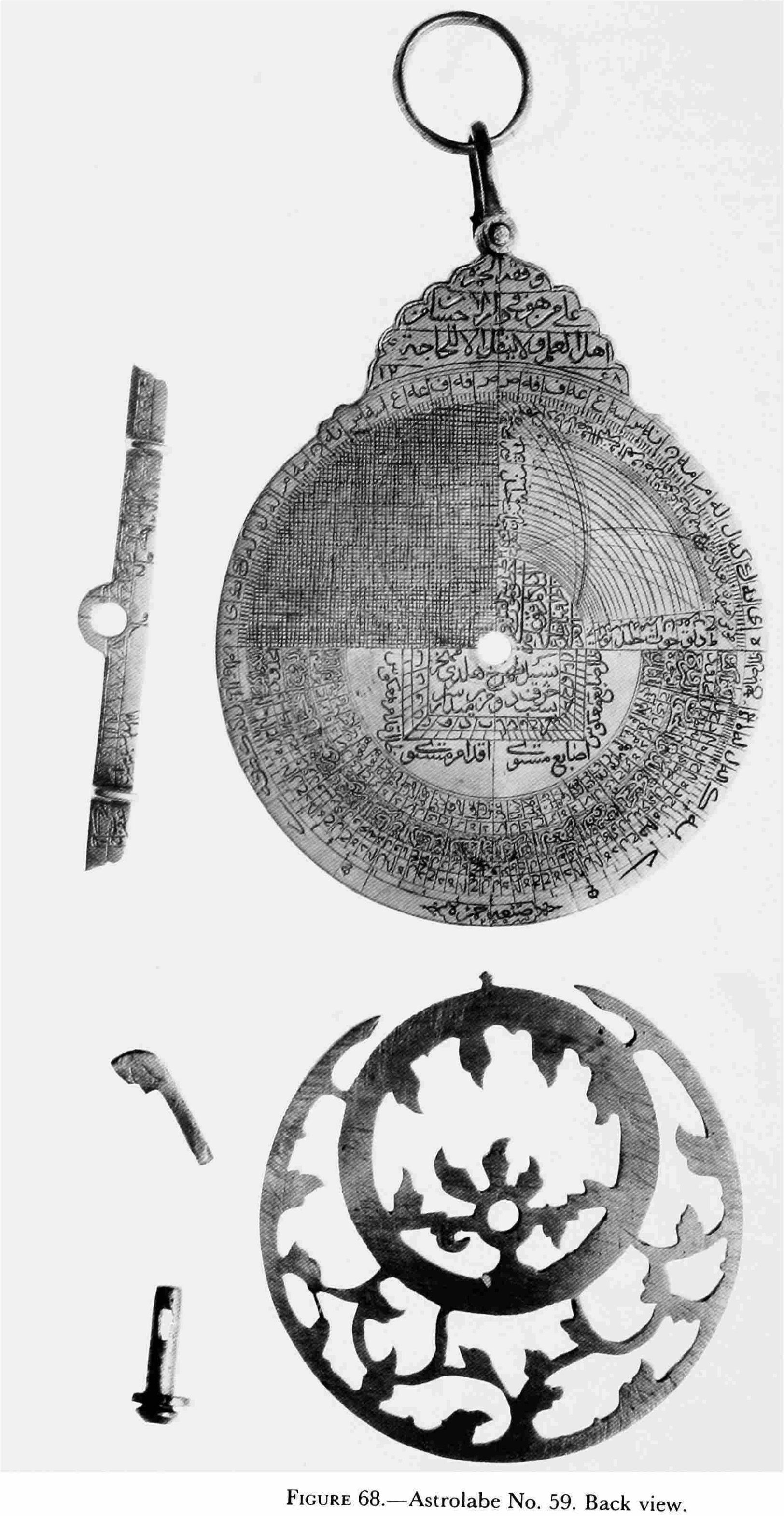


FIGURE 68.—Astrolabe No. 59. Back view.

graved on the front central area which lists 46 place names with their longitudes, latitudes, azimuth of Qibla, and distance from Mecca.

On the back of the astrolabe, the outer margin contains altitude scales in the upper half and cotangent scales of feet (left) and fingers (right) in the lower half. There is a stereographically projected declination scale in the upper right quadrant. Four lines have been engraved on this scale representing the azimuth of the Qibla at Ṭus (bottom), Iṣfahan, Baghdad, and Shiraz. For a transcription and translation of the inscription relating to these lines (inside the innermost declination arc), see No. 49. Also graphed on the declination arcs are fine lines representing the altitude of the noon sun at every 2° of latitude between 26° and 42°. An Arabic inscription outside the outermost declination arc relates to this graph:

دوائر انصاف النهار فى العروض المرقومة

على اطرافها .

It translates: "Circles of midday in the latitudes marked at their extremities" (GS).

Sines and cosines have been engraved on the upper left quadrant at sexagesimal intervals. Shadow squares in the lower quadrants have been divided into feet (left) and fingers (right). A Persian inscription is engraved inside the squares:

نسيل تهرخ هلدى مهخر

بشب حرف دوم ميد ار بر سر

This is a poetic code (explained at CCA No. 61) for the rulers of the triplicities. It translates: "At night the second letter is kept in mind." There are five semicircular astrological scales outside the shadow squares, which are the planetary governors of terms, the term divisions in degrees, the zodiacal signs, the planetary governors of faces, and the lunar mansions.

Each of four plates is notched at 270°. On one face there are engraved 51 quarter-horizons representing every degree of latitude between 12° and 62°. All remaining faces contain stereographically projected coordinates for a single latitude. On one plate (plate 2) these consist only of altitudes (every 6°) azimuths (every 10°), and unequal hours. The equal Italian hours have been added to other faces. The projections are identified with the following inscriptions:

Plate	*Latitude*		*Length of daylight*	
1b	*li-ᶜarḍ*	26	*sāᶜātuhu*	13 12
2a	*li-ᶜarḍ*	33	*sāᶜātuhu*	14 00
2b	*li-ᶜarḍ*	30	*sāᶜātuhu*	13 52
3a	*li-ᶜarḍ*	35	*sāᶜātuhu*	14 23
3b	*li-ᶜarḍ*	34	*sāᶜātuhu*	14 18
4a	*aṣ-ṣafīḥa mizān al-ᶜankabūt*			
4b	*li-ᶜarḍ*	36	*sāᶜātuhu*	14 27

The relativity simple rete pattern includes a counterchanged equinoctial colure inside the ecliptic. A branching vine springs up from the lowest part of the Capricorn circle. There are 30 inscribed star pointers. The ecliptic is subdivided into units of 6°. Lines making the colures, tropics, and equator are visible on the front of the rete. The alidade has no counterchanges. Both arms have been divided into 60 units along the beveled edge. On the flat of one arm there are portions of six stereographically projected declination arcs; on the other, there are five sundial divisions. Each sighting plate is pierced with two holes above the fiducial line. In each case the upper hole is larger. The pin is a bolt with hemispherical head. The ringlet has a rectangular cross-section. The wedge is shaped like a pistol.

The Naskhi script is used to inscribe both Arabic and Persian phrases on this instrument.

Remarks: Both Ḥamza's signature and the date appear in the lower margin of the back of the instrument. There are no other known astrolabes with this signature; however, the rete pattern adopted by Ḥamza is one used by makers in Iṣfahan (notably ᶜAbd al-Aᵓimma) in the eighteenth century. Some dotted lines are used in the upper quadrants on the back of Ḥamza's astrolabe.

CCA No. 61

(Figures 69, 70)

Date: A.H. 1281 [1864].
Signature: See "Remarks."
Components: Body with throne (cast in one

FIGURE 69.—Astrolabe No. 61. Front view.

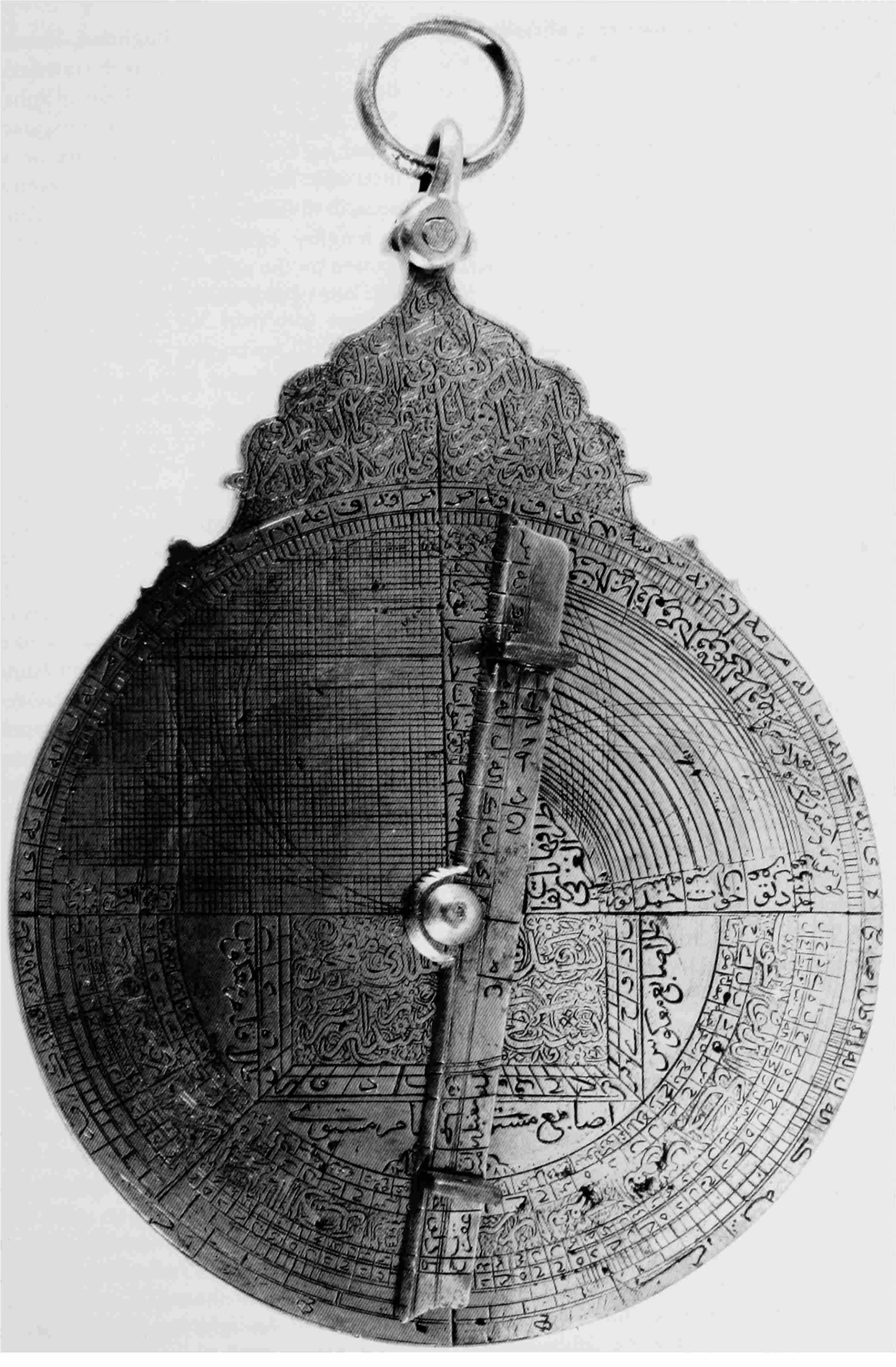


FIGURE 70.—Astrolabe No. 61. Back view.

piece), handle, ring, five plates, rete, alidade, pin, and wedge.

Diameter: 118.5 mm.

Material: Brass.

Characteristics: The throne is a high Moorish arch inscribed on both faces. The inscription on the front consists of a list of God, Muḥammad, the 12 Imams, and a blessing, as follows:

الله محمد المصطفى على المرتضى حسن المجتبى
حسين الشهيد على زين العابدين محمد الباقر
جعفر الصادق موسى الكاظم على الرضا محمد التقى
على النقى حسن العسكرى محمد المهدى عليهم
صلوات الله وسلامه اجمعين .

The blessing may be translated, "May the prayers and peace of God be upon them all" (GS). The inscription on the back consists of the following quotation from the Koran:

وإن يكاد الذين كفروا ليزلقونك بابصارهم لما
سمعوا الذكر او يقولون إنه لمجنون . وما هو
الا ذكر للعالمين .

It translates: "And lo! those who disbelieve would fain disconcert thee with their eyes when they hear the Reminder, and they say: Lo! he is indeed mad; when it is naught else than a Reminder to Creation" (GS).

The handle is stirrup-shaped and has a diamond cross-section. The ring has no visible join; its cross-section is a flattened circle. The rim is divided into 360° The front central area contains a gazetteer consisting of 52 named places along with the longitude (measured from the Fortunate Isles), their latitude, the azimuth of the Qibla, and the direction of the azimuth of the Qibla for each. The back margin contains altitude scales divided into degrees in the upper quadrants and cotangent scales divided into feet (left) and fingers (right) in the lower quadrants. The upper right quadrant contains a set of stereographically projected declination arcs (separated by 10° or 6° intervals) intersected by graphs indicating (1) the altitude of the noon sun at 11 latitudes (beginning at 22° and separated by 3° intervals between 23° and 50°) and (2) the azimuth of the Qibla at Ṭus, Yazd, Iṣfahan, Baṣra, Baghdad, Shiraz, and Kufa (?). For transcriptions and translations of the inscriptions relating to these graphs, see CCA Nos. 49 and 59. The upper left quadrant is divided by both sines and cosines at sexagesimal intervals. Both lower quadrants contain shadow squares divided into feet (left) and fingers (right). A lengthy embossed inscription fills the area framed by the adjacent shadow squares. That the first line of this inscription,

نسيل تهرخ هلدى مهخر

is a mnemonic for the astrological triplicities is suggested by the second line, which reads

بشب حرف دوم ميد ار بر سر

and may be roughly translated, "At night the second letter is kept in mind" (GS). The first letter in each "word" in the first line stands for one of the four natures: *Nārī* (fiery), *Turābī* (earthy), *Hawāʾī* (airy), *Māʾī* (watery). The second letter represents the planetary lord of the day associated with that nature: *Shams* (sun), *Zuharah* (Venus), *Zuḥal* (Saturn), and *Zuharah* (Venus). The third letter represents the appropriate planetary lord of the night: *Mushtarī* (Jupiter), *Qamar* (moon) *ʿUṭārid* (Mercury), and *Mirrīkh* (Mars). The fourth letter represents those planets that, according to their nature, have dominion both day and night: *Zuḥal* (Saturn), *Mirrīkh* (Mars), *Mushtarī* (Jupiter), and *Qamar* (moon). A name, Ṣaḥib ʿAli Kabir Khan, and date, 1281, are inscribed in a cartouche below the shadow squares. The following semicircular tables fill the area between the shadow squares and the cotangent scales (beginning with the outermost and proceeding inward): planetary governors of terms, terms, zodiacal signs, planetary governors of faces, and lunar mansions. (An unidentifiable semicircular scale lies between the cotangent scale and the table of planets; it is divided into unequal sections but not inscribed.)

Eight plate faces are engraved with the standard network of lines including altitudes at 3° intervals and azimuths at 10° intervals. A latitude and length of daylight has been embossed below the horizon on each plate face as follows:

Plate	*Latitude*		*Length of daylight*	
1b	*ᶜarḍ*	45	*sāᶜātuhu*	22 00
2a	*ᶜarḍ*	22	*sāᶜātuhu*	13 21
2b	*ᶜarḍ*	25	*sāᶜātuhu*	13 30
3a	*ᶜarḍ*	28	*sāᶜātuhu*	13 42
3b	*ᶜarḍ*	34	*sāᶜātuhu*	14 17
4a	*ᶜarḍ*	30	*sāᶜātuhu*	13 36
4b	*ᶜarḍ*	38	*sāᶜātuhu*	14 39
5a	*ᶜarḍ*	32	*sāᶜātuhu*	14 07

A ninth plate face (5b) contains the standard network (utilizing 3° and 10° intervals) supplemented by a stereographic projection of the Italian hours. The latitude and length of daylight embossed below the horizon are 36 and 14 18. The tenth plate (1a) face contains stereographically projected colures, tropics, equator, and quarter-horizons for every degree of latitude between 14° and 66°; scales of declination (with 2° and 4° divisions, the latter inscribed) are also included.

The rete is inscribed with the names of 27 stars. Its relatively simple pattern includes a counterchanged equinoctial colure and a modified Moorish arch in the area between the projection of the ecliptic circle and the Tropic of Capricorn. The ecliptic band is subdivided into units of 6°. Tropics, equator, and ecliptic divisions have been engraved on the back of the rete. The alidade is not counterchanged, but it includes a beveled fiducial edge and sighting plates, each pierced with two holes of slightly different diameter. The plates are separated by a distance of 71 mm. Scales engraved on the arms of the alidade include a set of declination arcs (distributed in the same way as the declination arcs on the back of the body), a scale of sexagesimal divisions, and a shadow scale. The pin is a bolt; the wedge is the head of an animal.

The inscription is entirely Arabic Naskhi, except for the Hindu-Arabic numerals used to designate latitudes on the horizon plate.

Remarks: The degree scale on the rim of the instrument is engraved as if it were going to be used as an altitude scale; the 5° divisions in each quadrant are numbered from "5" to "90." In the selection and ordering of the series of cities in the inner circle of its gazetteer, the instrument closely resembles Nos. 59 and 62. Scales and networks of lines are characterized by a lack of precision. The bolt, the wedge, and the sighting plate on the arm of the alidade engraved with declination arcs all appear to be modern replacements. The name in the cartouche below the shadow squares may be identified only tentatively as that of the instrument's maker. The possibility that he may be its owner is suggested by the fact that his signature differs noticeably from the other writing on the astrolabe. No other astrolabes have been attributed to this "maker."

CCA No. 62

(FIGURES 36, 71, 72)

Date: A.H. 1281 [1864].

Signature: ᶜamal ᶜAlaʾ al-Din.

Components: Body with throne, two rings, five plates, rete, alidade, pin, and wedge.

Diameter: 120.5 mm.

Material: Brass.

Characteristics: The throne is broad and shaped like a bracket. It is decorated on front and back with two engraved parallel lines that follow the edges. The suspensory apparatus consists of two rings. The rim contains four scales of 90°. Two of these proceed clockwise starting at 0° and 180°. Two scales proceed in a counterclockwise direction starting at 0° and 180°. The *abdjad* numbers identifying subdivisions of this scale are bracketed in groups of three. A tooth projects from the rim into the front central area. The front central area contains an incomplete gazetteer that lists 23 places and associates each with a longitude, a latitude, an azimuth of the Qibla, and a direction of the azimuth of the Qibla.

The upper half of the outer margin on the back of this astrolabe contains altitude scales. The lower half contains cotangent scales divided into feet (left) and fingers (right). Stereographically projected declination arcs fill the upper right quadrant. Several lines have been engraved on these arcs, six representing the altitude of the noon sun at various unspecified latitudes and one representing the azimuth of the Qibla at an un-

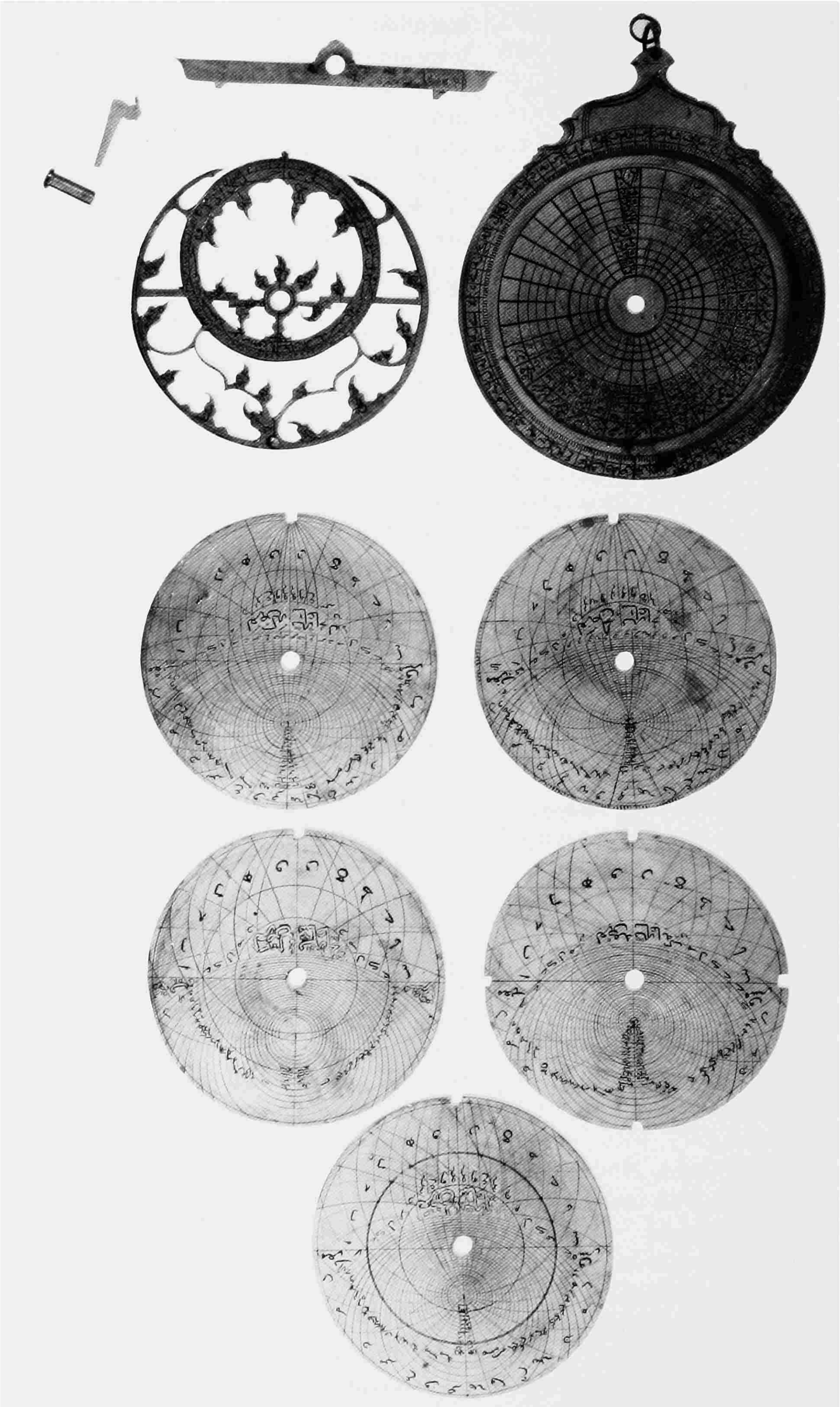


FIGURE 71.—Astrolabe No. 62. Front view of separate parts.

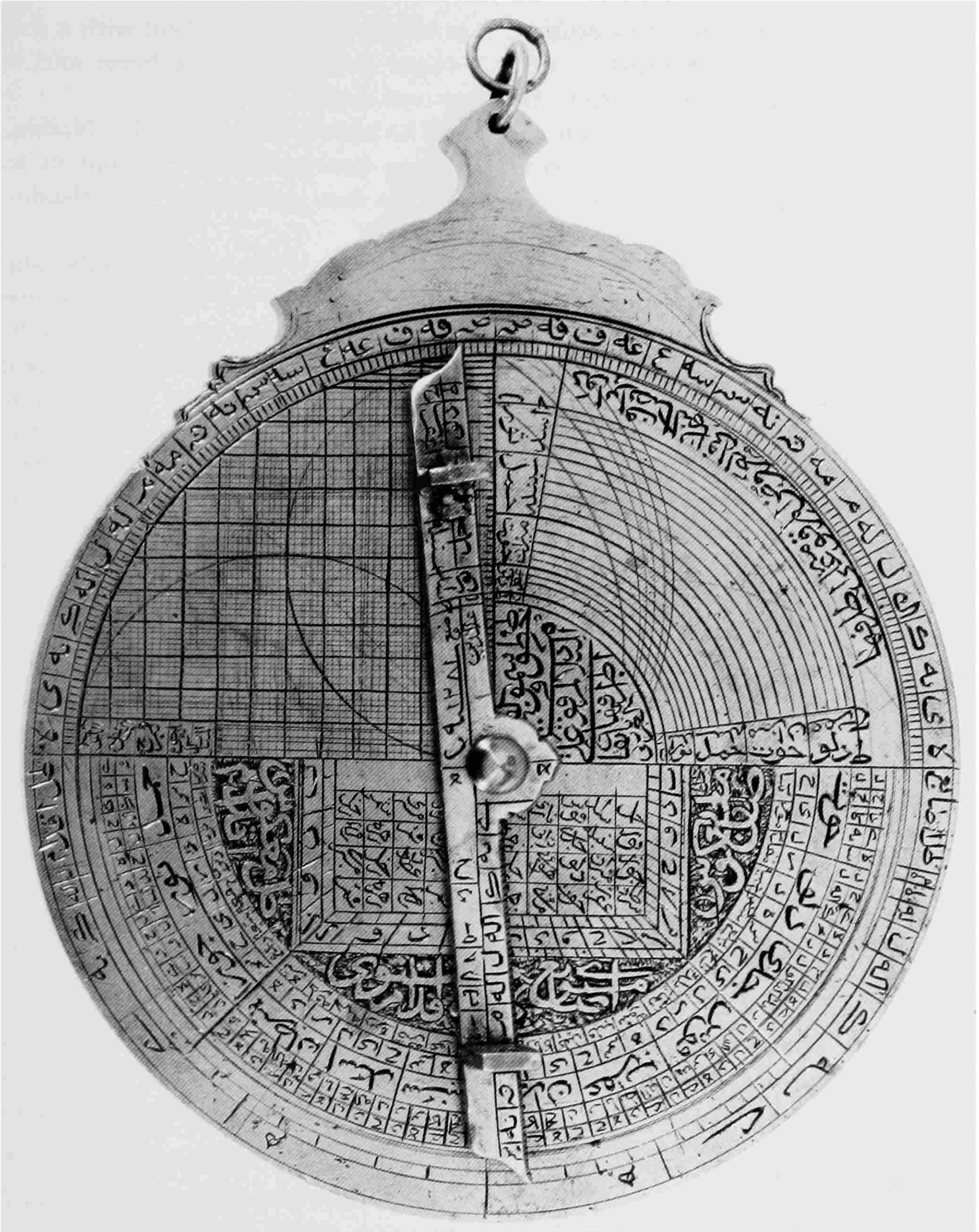


FIGURE 72.—Astrolabe No. 62. Back view.

known city. (For a transcription and translation of the inscription relating to the altitude scale, see CCA No. 59. For a transcription and translation of the inscription relating to the azimuth arcs, see CCA No. 49.)

Sines and cosines have been engraved at sexagesimal intervals in the upper left quadrant. The radii of this quadrant are the diameters of two intersecting semicircles. Shadow squares in the lower quadrants have been divided into feet (left) and fingers (right). The area inside these shadow squares has been divided into a rectangular scale of triplicities. The natures are identified using Arabic terminology. The area outside the squares

contains a cartouche inscribed with the signature and date and five semicircular astrological scales, including: the planetary governors of terms, the position of each term boundary within each zodiacal sign, the zodiacal signs, the planetary governors of the faces, and the lunar mansions.

There are five plates. Four of these are notched at 270°. One is notched at 0°, 90°, 180°, and 270°. One face of the plate with the four notches contains 53 quarter-horizons representing every degree of latitude between 14° and 66°. On this same face there are also four scales indicating declination. All other plate faces contain stereographically projected coordinates for a single latitude. On seven faces the coordinates include altitudes (every 3°), azimuths (every 10°), and unequal hours. On both faces of plate 5 the coordinates include altitudes (every 3°), azimuths (every 10°), unequal hours, and equal Italian hours. The plate faces are identified with inscriptions as follows:

Plate	*Latitude*	*Length of daylight*
1b	*li-ʿarḍ* 45	*sāʿatuhu* 15 22
2a	*li-ʿarḍ* 22	*sāʿatuhu* 13 21
2b	*li-ʿarḍ* 24	*sāʿatuhu* 13 30
3a	*li-ʿarḍ* 28	*sāʿatuhu* 13 00
3b	*li-ʿarḍ* 34	*sāʿatuhu* 14 17
4a	*li-ʿarḍ* 32	*sāʿatuhu* 14 7
4b	*li-ʿarḍ* 30	*sāʿatuhu* 13 36
5a	*li-ʿarḍ* 36	*sāʿatuhu* 14 27
5b	*li-ʿarḍ* 38	*sāʿatuhu* 14 39

The rete pattern incorporates a complete, counterchanged equinoctial colure. Most of the support for star pointers comes from a branching vine, which springs from the lowest point on the inner edge of the Capricorn band. There are 27 inscribed star pointers. The ecliptic is subdivided into units of 6° There are a number of lines engraved on the back of the rete, including divisions of the ecliptic and Capricorn bands. The alidade is not counterchanged. One arm contains portions of six stereographically projected declination arcs. The other arm is divided into 60 equal units along the beveled edge and into five sundial marks along the flat. The maker's signature and date are also inscribed on the alidade. Of the two holes in each sighting plate, the upper is larger. The pin is a bolt with a flat head. The wedge is shaped like a horse and includes engraved details.

The inscription is in Arabic Naskhi. The equal Italian hours and the declination scale on the horizon face are marked with Hindu-Arabic numerals.

Remarks: While this astrolabe appears to be functional, it is not impressively precise. Some divisions (as those in the upper left quadrant) seem crudely drawn. There are crude divisions on the horizon plate face. The alidade, pin, and wedge described in this catalog entry do not appear in photos taken by Hoffman. The latter two (pin and wedge) apparently replaced the screw and wing nut photographed by Hoffman.

CCA No. 63

(Figures 73, 74)

Date: See "Remarks."

Signature: See "Remarks."

Components: Body with throne, handle, eight plates, rete, alidade, pin, and wedge.

Diameter: 128 mm.

Material: Brass.

Characteristics: The throne is quite high and triangular in shape, with scalloped edges. On the front of the throne, large embossed letters spell out the beginning of the throne inscription: "His throne includes the heavens and the earth" (see CCA No. 39). On the back of the throne there is a lengthy engraved inscription which reads:

طول وعرض بلاد منقوش در حجره • طول از
رصد موضع کرینج لندن • وعرض از خط استوی
کما هو المشهور • منقول از••• وانحراف از
مکه معظمه وجهة آن یدفت تمام بعمل جیب
ظل فرنکی استخراج شده •

میرزه جهان بخش

(see "Remarks" for translation). The handle is shaped like an elongated stirrup. A scale of 360° divides the rim. The first division is marked "5,"

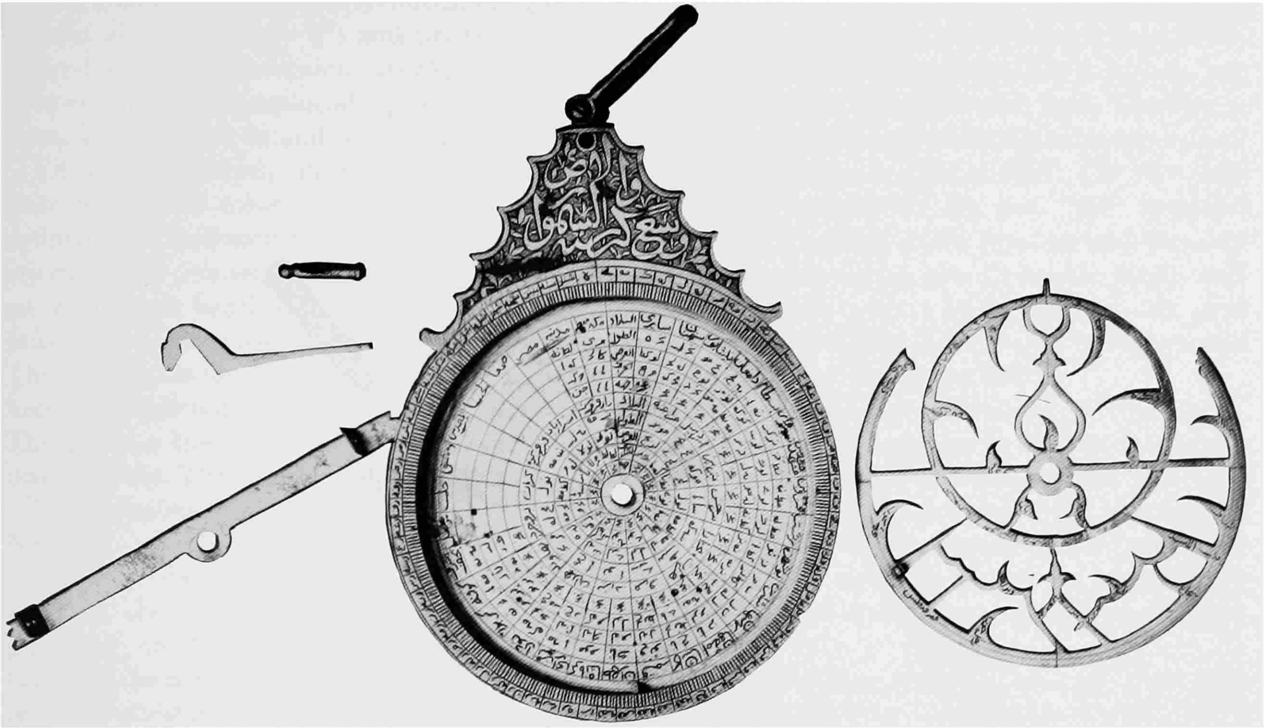


FIGURE 73.—Astrolabe No. 63. Gazetteer.

the last, "360," in *abdjad* numerals. There is a tooth projecting into the front central area at 270°. Engraved on the front central area is a gazetteer with longitude, latitude, azimuth of the Qibla, and direction of Mecca for 42 named places. The inscription is incomplete.

On the back of the astrolabe, altitude scales divide the upper margin. The lower margin contains cotangent scales divided into feet (left) and fingers (right). The upper right quadrant contains equally spaced declination arcs. Seven lines representing the azimuth of the Qibla have been graphed on these arcs. The lines are identified as follows:

مدینه بصره اصفهان طوس قندهار شستر
ملتان

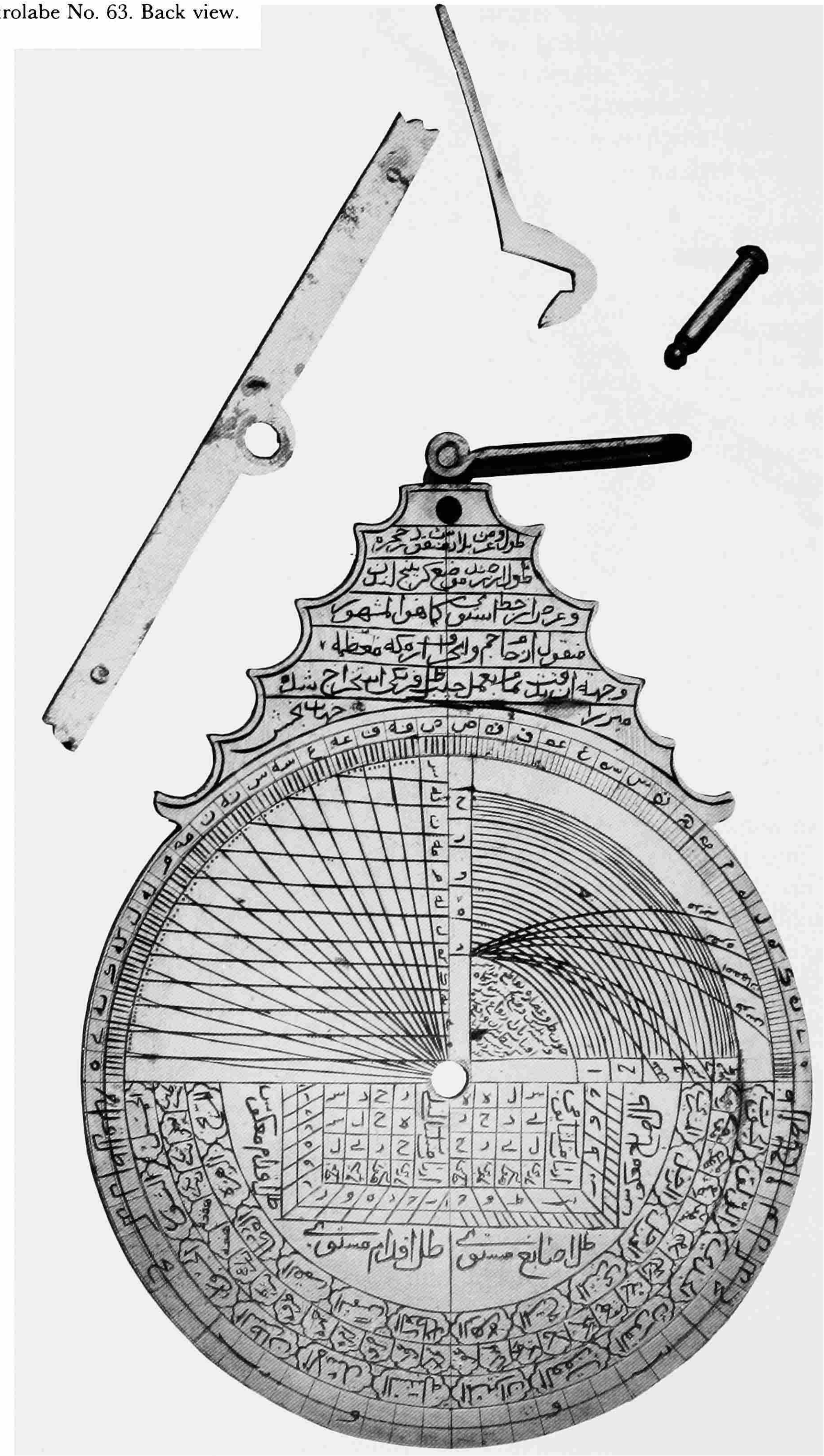
or: Multan (lowest), Shustar, Qandahar, Ṭus, Iṣfahan, Baṣra, and Medina. The inscription inside the innermost declination arc provides instructions for finding the Qibla:

جون طرف عضاده بر تقاطع مدار شمس وسمت
بر بلدی وضع کنید بر کاه افتاب بآن ارتفاع
رسید که شظیه بر آن واقع شده در سمت قبلة
باشد در آن بلد

In the upper left quadrant, there are 13 equally spaced sine lines. In addition, there are radii every 5°. The shadow squares in the lower quadrants are divided into feet (left) and fingers (right). There is a scale of triplicities inside the squares. The natures are identified using both Arabic and Persian terms. Outside the squares, there are three semicircular astrological scales: zodiacal signs, lunar mansions, and planetary governors of the zodiacal signs. The inscription in each division is contained within brackets.

The astrolabe has been fitted with eight plates, each notched at 270°. Plate face 1a is illegible. Plate 2a contains altitudes, and 3a contains altitudes marked at every 6°, unequal hours, and an

FIGURE 74.—Astrolabe No. 63. Back view.



arch of unknown significance. All remaining faces contain altitudes (every 6°) and unequal hours. There is only one inscription identifying the latitude of the stereographically projected coordinates. It is on plate 8a and reads "34 98 ᶜarḍ 34."

The rete is relatively simple. It includes a complete equinoctial colure and part of the equator defined by a scalloped band. In all, there are 22 inscribed star pointers. There are no subdivisions on the ecliptic band. Engraved colures and Capricorn circle are visible on the front of the rete. The alidade has no counterchanges and no markings. Each sighting plate is pierced with two holes. The pin is a bolt with hemispherical head and doorknob tip. The wedge is shaped like a horse.

The alphabet employed by the maker is Arabic Naskhi.

Remarks: This astrolabe is quite similar, especially in the content and arrangement of the gazetteer, to CCA No. 3811. According to Gunther, the entries in the gazetteer are explained in the inscription on the back of the throne: "Longitude and latitude of countries are recorded on the Hajrah. Longitude from the Observatory of Greenwich, London. Latitude from the Equator as is well known, is taken from dictionaries (?), and the direction from Mecca extracted from the European sine of the shadow. All completed by Mirza Jahan Bakhsh." There are no other instruments with this signature. There are several indications on this instrument that the maker was a careless worker. For example, the sine scale does not originate at the center of the back of the astrolabe. The declination arcs, some of them dotted, are quite carelessly drawn. Altitudes and hour divisions are also carelessly projected.

CCA No. 64

(FIGURE 75)

Date: Ca. A.D. 1850.

Signature: None.

Components: Body with throne, handle, ring, four plates, rete, alidade, pin, and wedge.

Diameter: 148 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch and pierced with three large holes. The handle is basically shaped like a stirrup, but its top is shaped like a Moorish arch. The ring is a scalloped circle with rectangular cross-section. The rim contains a scale of 360°. The first subdivision is marked "5;" the last, "360" in *abdjad* numerals. Inscribed in the front central area is a worn gazetteer which lists 23 legible places and associates each with a longitude, latitude, and azimuth of the Qibla. A small post interrupts this inscription near the rim at 270°.

On the back of the astrolabe, altitude scales occupy the upper margin. In the lower margin, there are cotangent scales divided into feet (left) and fingers (right). The upper right quadrant is blank. Sines have been engraved in the upper left quadrant. The lower quadrants are occupied by shadow squares divided into feet (left) and fingers (right).

There are four plates. Three of these are notched at 270°; one is notched at 0°, 90°, 180°, and 270°. One face of the multi-notched plate (3a) is inscribed with 28 quarter horizons representing every 2° of latitude between 12° and 66° There are also four scales of declination along the outer ends of the projected colures. All other plate faces, including the reverse of the horizon plate, contain a sterographically projected network of coordinates for a single latitude. On plate faces 1a, 2a, 3b, and 4a these coordinates include altitudes (every 2°), unequal hours, and equal Italian hours. On plate faces 1b and 2b these coordinates include altitude (every 2°), azimuths (every 5° or every 10°), and unequal hours. Plate face 4b contains altitudes, azimuths, unequal hours, and equal Italian hours. The plates are inscribed as follows:

Plate	*Latitude*	*Length of daylight*
1a	ᶜ*arḍ* 30 00	*sāᶜātuhu* 13 57
1b	ᶜ*arḍ* 28 00	*sāᶜātuhu* [?] 39
2a	ᶜ*arḍ* 38 05	*sāᶜātuhu* 14 38
2b	ᶜ*arḍ* 36 00	*sāᶜātuhu* 14 29
3b	ᶜ*arḍ* 42 08	*sāᶜātuhu* 15 04
4a	ᶜ*arḍ* 34 00	*sāᶜātuhu* 14 17
4b	ᶜ*arḍ* 32 00	*sāᶜātuhu* 14 07

The rete pattern includes a straight equinoctial

FIGURE 75.—Astrolabe No. 64. ᶜ*Ankabūt.*

colure and a portion of celestial equator between ecliptic and Capricorn band. The central support of the celestial equator is shaped like foliage. There are 22 inscribed star pointers. The ecliptic is subdivided into units of 6°. The alidade is not counterchanged, inscribed, or decorated. There are two holes and a notch above the fiducial line on each sighting plate. The pin is a bolt with hemispherical head and doorknob tip. The wedge is shaped like a horse with engraved details.

The alphabet employed by this maker is Arabic Naskhi.

Remarks: This astrolabe is almost identical with CCA No. 2566. The rete of one is the image of the rete of the other, except that the rete of No. 2566 has one more star pointer than that of this astrolabe. Any identifying inscription that may once have been on the "extra" pointer has since been obliterated. The gazetteers are also alike in content and arrangement. The similarity

is obvious even though the gazetteer of this instrument is partially obliterated. The rim divisions appear carelessly executed: The same can be said of the sine lines in the upper left quadrant. There are numerous dents and scratches on the back of this astrolabe. Carelessness is also evident in the inscription on the plates. The rete of this astrolabe is less finely cut than the rete of No. 2566, and the back of this astrolabe seems incomplete. Thus, the evidence suggests that the astrolabe being described in this entry may be a copy of the astrolabe described in No. 2566 or that both astrolabes derive from a third, as yet unidentified, instrument. The approximation of the date of this instrument is based on the placement of the stars on the rete, and, if one accepts the premise that workmanship has declined over time, the quality of the workmanship.

CCA No. 65

(FIGURES 33, 76, 77)

Date: Ca. A.D. 1750
Signature: None.
Components: Body with throne, handle, ring, four plates, rete, alidade, pin, and wedge.
Diameter: 114 mm.
Material: Brass
Characteristics: The throne is unsigned, undecorated, and unpierced. Its shape is a broad, symmetric Moorish arch. The stirrup-shaped handle has a triangular cross-section. The ring has a circular cross-section. The rim is divided by a scale of 360°. The last unit is inscribed with the *abdjad* numeral "60." The front central area contains a gazetteer listing 46 place names along with the latitude, longitude, azimuth of the Qibla, and direction of azimuth for each place named.

There is an altitude scale in the upper margin on the back of this instrument. A cotangent scale divided into feet (left) and fingers (right) fills the lower margin. A stereographically projected declination scale divides the upper right quadrant. Upon it have been graphed lines representing the altitude of the noon sun for every 2° of latitude between 28° and 40°, and lines representing the

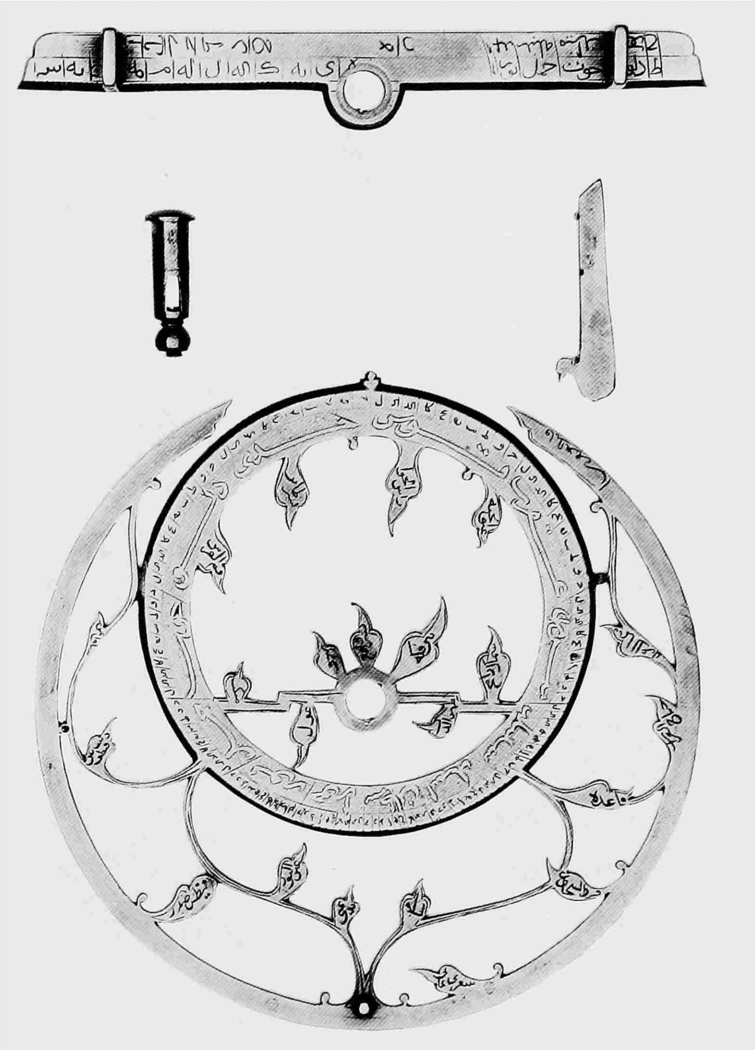


FIGURE 76.—Astrolabe No. 65. ᶜ*Ankabūt* and alidade.

azimuth of the Qibla for Ṭus (bottom), Iṣfahan, Baghdad, and Shiraz. The inscription inside the innermost declination arc relating to the azimuth graph is transcribed and translated in the description of CCA No. 49. The inscription outside the outermost declination arc relating to the altitude graph is transcribed and translated in the description of CCA No. 59. Sixty sines and as many cosines divide the upper left quadrant. The two lower quadrants contain shadow squares divided into feet (left) and fingers (right). Outside these squares are semicircular astrological scales of planetary governors of terms, term divisions, zodiacal signs, and planetary governors of faces.

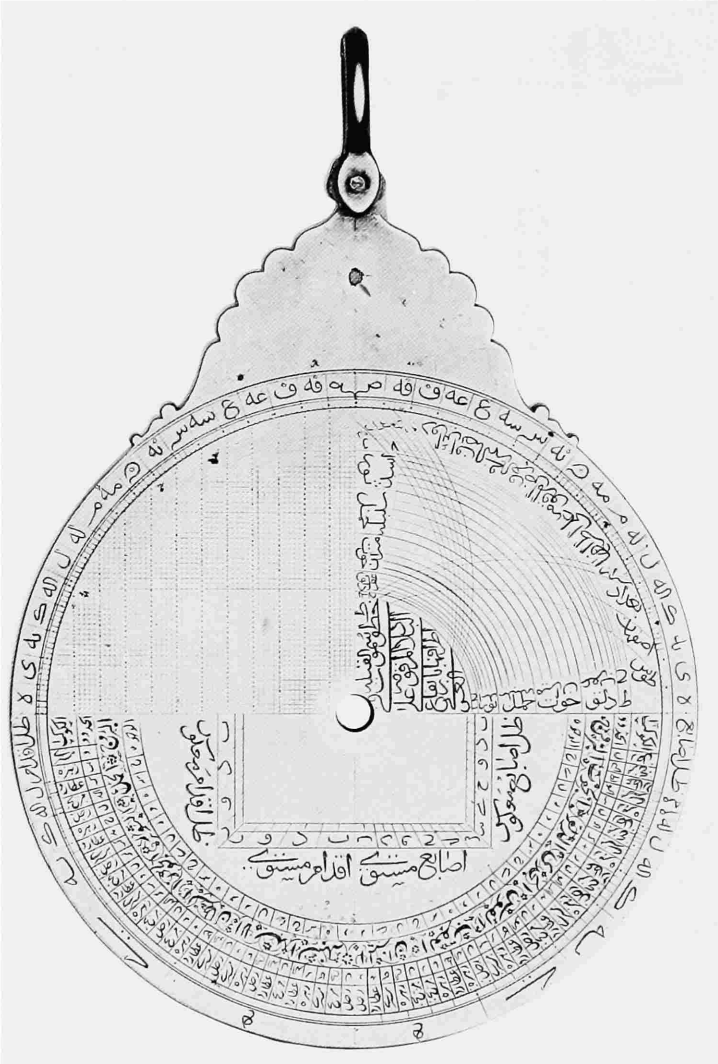


FIGURE 77.—Astrolabe No. 65. Back view.

Each of the instrument's four plates is notched at 270°. Plate face 1a contains only projected quarter-horizons, one for each degree of latitude between 14° and 66°. All other plate faces contain a stereographically projected reference frame for a single latitude, consisting of a horizon and altitudes (every 3°), azimuths (every 10°), unequal hours, and astrological houses. The plate faces are inscribed as follows:

Plate	*Latitude*	*Length of daylight*
1b	^{c}*arḍ* 42 00	*sā^{c}ātuhu* 15 07
2a	^{c}*arḍ* 28 00	*sā^{c}ātuhu* 13 47
2b	^{c}*arḍ* 30 00	*sā^{c}ātuhu* 13 56
3a	^{c}*arḍ* 32 00	*sā^{c}ātuhu* 14 07
3b	^{c}*arḍ* 34 00	*sā^{c}ātuhu* 14 17
4a	^{c}*arḍ* 36 00	*sā^{c}ātuhu* 14 27
4b	^{c}*arḍ* 38 00	*sā^{c}ātuhu* 14 39

The rete's design incorporates an inverted Moorish arch between the ecliptic band and the Capricorn band. A counterchanged portion of the equinoctial band connects the ecliptic with the central circle. The ecliptic band is subdivided into units of 3° There are 23 inscribed star pointers. Straight lines and circles are engraved on the back of the rete. The alidade arm contains on one arm divisions coinciding with the declination scale and on the other arm divisions coinciding with the sine/cosine grid and sundial divisions. Each sighting plate is pierced with two holes, with the upper larger. The pin is a bolt with flattened hemispherical head and doorknob tip. The wedge is shaped like a duck.

The alphabet employed by the maker is Arabic Naskhi.

Remarks: Several aspects of its design distinguish this instrument from other astrolabes with which it can be compared. The embossed and stippled decoration typical of other eighteenth-century astrolabes made in the Middle East is notably lacking on this example. Engraved vines and flowers surround only one astrological scale. There is no scale of triplicities inside the shadow squares. The stereographically projected horizon reference frames are arranged on the plates in order of increasing latitude. Such an arrangement of plate faces is rare among Eastern makers. Finally, the plate faces contain house divisions distinct from the unequal hours, another practice rarely found among Eastern makers. These distinguishing elements combine with resembling elements. The rete, for example, has affinities with the rete of CCA No. 40. The selection and arrangement of the gazetteer is similar to that found on CCA No. 25. A dot emphasizes every fifth degree subdivision of the rim scale; this is also the case on No. 40. On this instrument the numeral signifying "90" on the right-hand altitude scale forms a design with the numeral signifying "90" on the left-hand altitude scale. The maker uses dotted lines to emphasize every fifth sine/cosine. A few errors mar the astrological scales. The unequal hours are named rather than numbered.

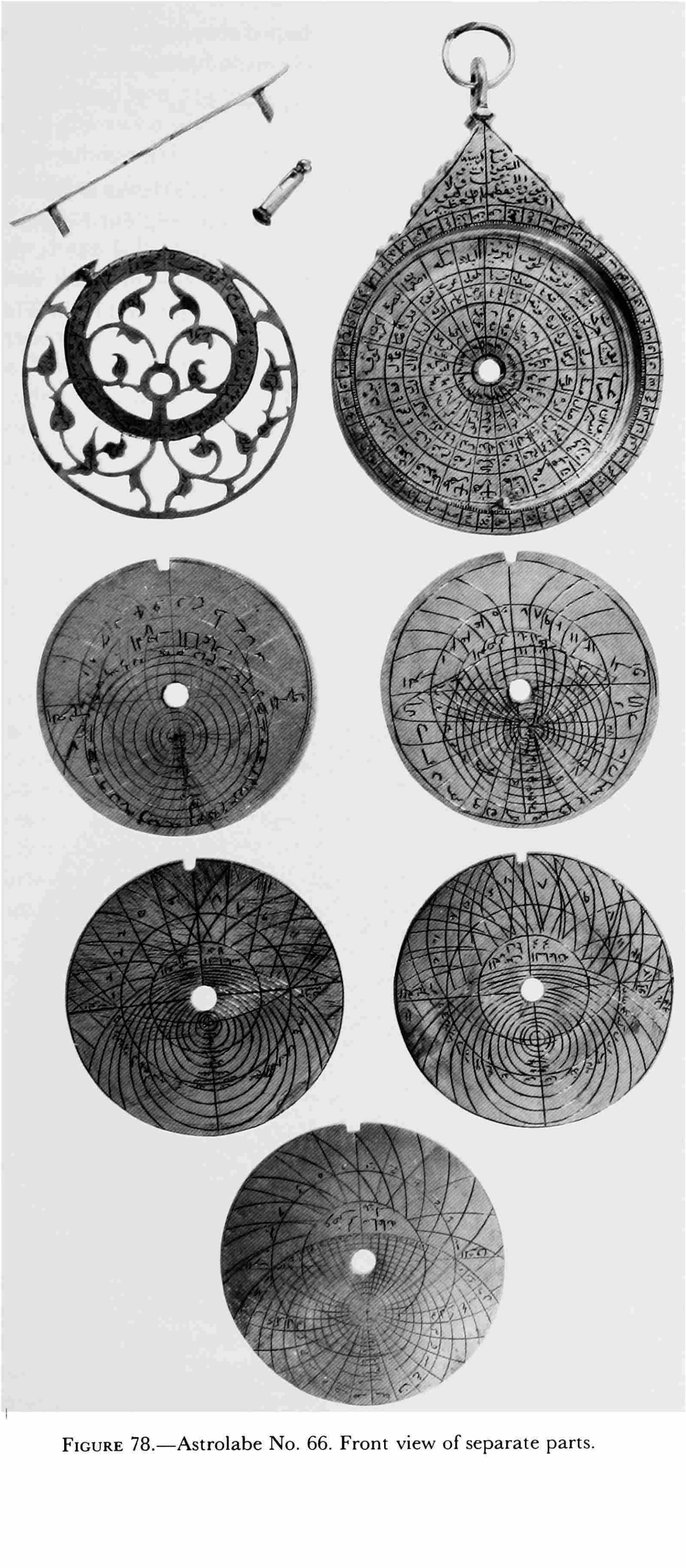


FIGURE 78.—Astrolabe No. 66. Front view of separate parts.

CCA No. 66

(FIGURES 78, 79)

Date: Ca. A.D. 1750.

Signature: None

Components: Body with throne and handle, ring, five plates, rete, alidade, pin, wedge.

Diameter: 89 mm.

Material: Brass.

Characteristics: The high, Moorish arch-shaped throne is decorated on the front with the following inscription:

وسع كرسيه السموات و الارض ولا يؤده حفظهما
وهو العلى العظيم

It can be translated as follows: "His throne holds the heavens and earth and He is not fatigued by keeping them and He is the High, the Great" (GS). The handle, cast in one piece with the throne, is a pierced disk. The ring has a circular

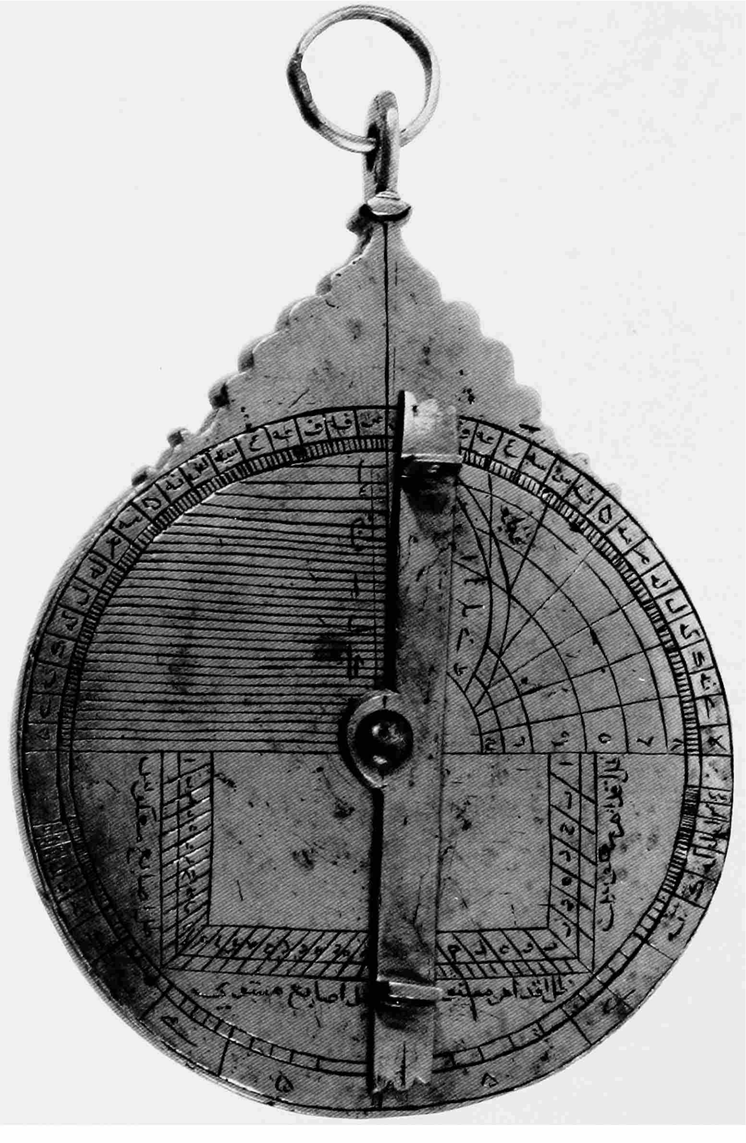


FIGURE 79.—Astrolabe No. 66. Back view.

cross-section. The rim is divided by four scales of 90°, two commencing at 0° and proceeding clockwise and counterclockwise, and two commencing at 180° and proceeding clockwise and counterclockwise. The scales are subdivided into units of 6°, each inscribed with *abdjad* numerals. The front central area contains a gazetteer listing 23 place names along with the longitude, latitude, azimuth of the Qibla, and direction of azimuth for each.

Altitude scales divide the upper margin of the back of this astrolabe. The lower margin contains cotangent scales divided into fingers (left) and feet (right). The upper right quadrant contains declination arcs and two lines apparently representing the azimuth of the Qibla for latitudes not given. One line is marked "Qibla." The upper left quadrant contains 30 sine lines. Shadow squares divided into fingers (left) and feet (right) occupy the lower quadrants.

All five plates are notched at 270°. Plate face 1a is divided by 28 quarter-horizons, one for every 2° of latitude between 10° and 66°. Horizons for 14° and 22° have been omitted. Three other plate faces (1b, 2a, 2b) contain stereographically projected horizon, altitudes (every 6°), azimuths (every 10°), unequal hours, and equal Italian hours for a single latitude. Six plate faces contain horizon, altitudes, azimuths, and unequal hours only. The plate faces are inscribed as follows:

Plate	*Latitude*		*Length of daylight*	
1b	*ʿarḍ*	37	*sāʿāt*	14 32
2a	*li-ʿarḍ*	30 00	*as-sāʿāt*	13 53
2b	*li-ʿarḍ*	32 00	*as-sāʿāt*	14 08
3a	*li-ʿarḍ*	34 00	*as-sāʿāt*	14 ?
3b	*li-ʿarḍ*	36 00	*as-sāʿāt*	14 31
4a	*li-ʿarḍ*	37	*as-sāʿāt*	14 34
4b	*li-ʿarḍ*	37 07	*as-sāʿāt*	15 35 (?)
5a	*li-ʿarḍ*	40	*as-sāʿāt*	15 14
5b	*li-ʿarḍ*		*sāʿāt*	

A remarkably symmetric rete pattern is formed by vines and flowers. Inside the ecliptic band vines form a *fleur de lis.* The ecliptic band is subdivided into units of 6°. There are only 13 recognizably inscribed star pointers. The alidade is neither counterchanged nor inscribed. The sighting plates are not pierced. The pin is a bolt with flattened hemispherical head and doorknob tip. The wedge is trapezoidal.

The maker has used Arabic Naskhi alphabet with some Hindu-Arabic numerals (hours).

Remarks: The workmanship evident in this instrument is of notably poor quality. Only the horizon plate escapes this assessment. The divisions on the back of the instrument are imprecise, though each is correctly numbered. Markings on plates 2–5 are consistently poor. The divisions on the rete's ecliptic band are uneven and identified with carelessly formed and poorly placed numerals. The alidade is nonfunctional.

CCA No. 70

(FIGURES 80, 81)

Date: A.H. 1020 [1611].

Signature: ʿAli ben ʿAwaḍ al-Maḥmudi.

Components: Body with throne (cast in one piece), handle, ring, rete, pin (with threads), and "wedge" (a square nut).

Diameter: 85.5 mm.

Material: Brass.

Characteristics: The high Moorish arch-shaped throne is pierced with five large holes and a small hole for the stirrup-shaped handle. The small ring exhibits no visible join. The rim is divided into 72 5° divisions (outer scale) and 360 1° divisions (inner scale). The 5° divisions are identified by *abdjad* numerals, proceeding clockwise beginning with a "5" in the first division to the right of 90° and ending with a "60" in the division to the left of 90°. The front central area contains a gazetteer listing 25 cities and their latitudes.

The back margin contains altitude scales in the upper quadrants. The margin in the lower quadrants is divided into inscribed 5° and uninscribed 1° cotangent scales. The upper left quadrant is divided by radii into 18 5° sectors; in addition, it is divided by a series of 11 roughly parallel and equally spaced horizontal lines. Finally, 10 concentric arcs of circles tangent to the parallel lines also divide the upper left quadrant. The upper

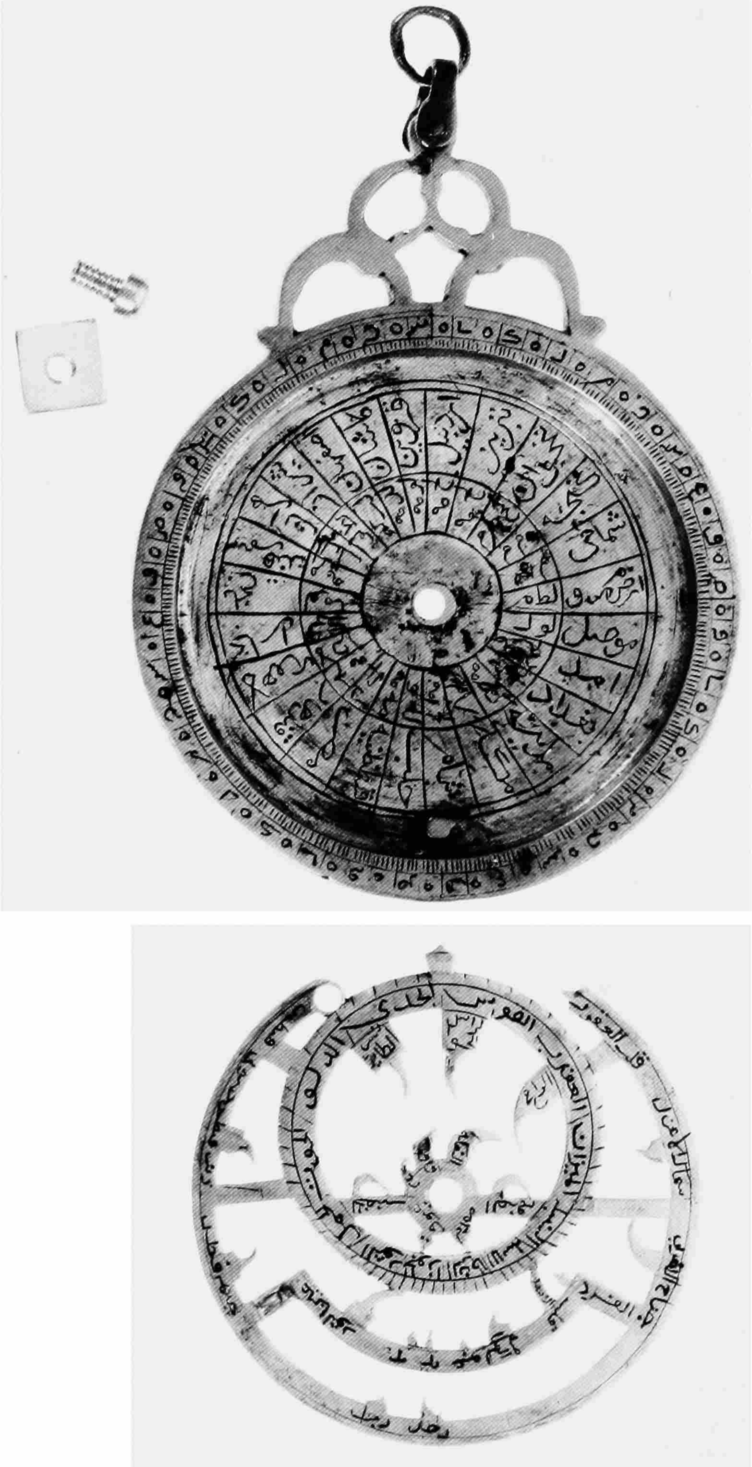


FIGURE 80.—Astrolabe No. 70. Gazetteer (top) with ʿ*ankabūt*.

right quadrant is divided into seven concentric bands of equal width. These are crossed by two prayer lines, inscribed *awwal aẓ-ẓuhr li-ʿarḍ 38* (upper line) and *awwal al-ʿaṣr* (lower line). The outer six of the concentric bands are numbered so as to suggest that they represent zodiacal divisions. The lower two quadrants are divided by shadow squares. Phrases which on any other instrument would be considered titles of shadow square scales are written along diagonals of the squares of this instrument: *ẓill al-aṣābiʿ* (on the left diagonal) and *ẓill al-aqdām* (on the right diagonal). The date of the instrument is inscribed inside the shadow squares. The maker's signature appears outside the lower border of the squares.

No plates belonging to this astrolabe have been preserved.

The rete is inscribed with the names of 25 stars. The ecliptic band is subdivided into units of 6°. A few construction guidelines appear on the back of the rete. The pattern of the openwork is relatively simple, consisting of a counterchanged, complete equinoctial bar and an arc of the projected celestial equator.

A screw with cylindrical head and a square nut hold the rete inside the body. No alidade is preserved.

Both scales and signature are inscribed in Arabic Naskhi.

Remarks: This instrument is functional, but rather carelessly engraved. (For example, on the rim scale, the symbol for 100 also identifies divisions 200 and 300.) The back of the astrolabe bears a striking similarity to one "finished" by Muḥammad Ṣaffar in A.H. 882 [1477].[105] ʿAli ben ʿAwaḍ's signature is known to appear on a second astrolabe, preserved in the Topkapi Museum in Istanbul (CCA No. 3705).

CCA No. 85

(FIGURES 82, 83)

Date: Ca. A.D. 1682.

Signature: Qasim ʿAli Asṭurlabi Qaʾini.

Components: Body with throne, handle, ring, six plates, pin, and wedge.

FIGURE 81.—Astrolabe No. 70. Back view.

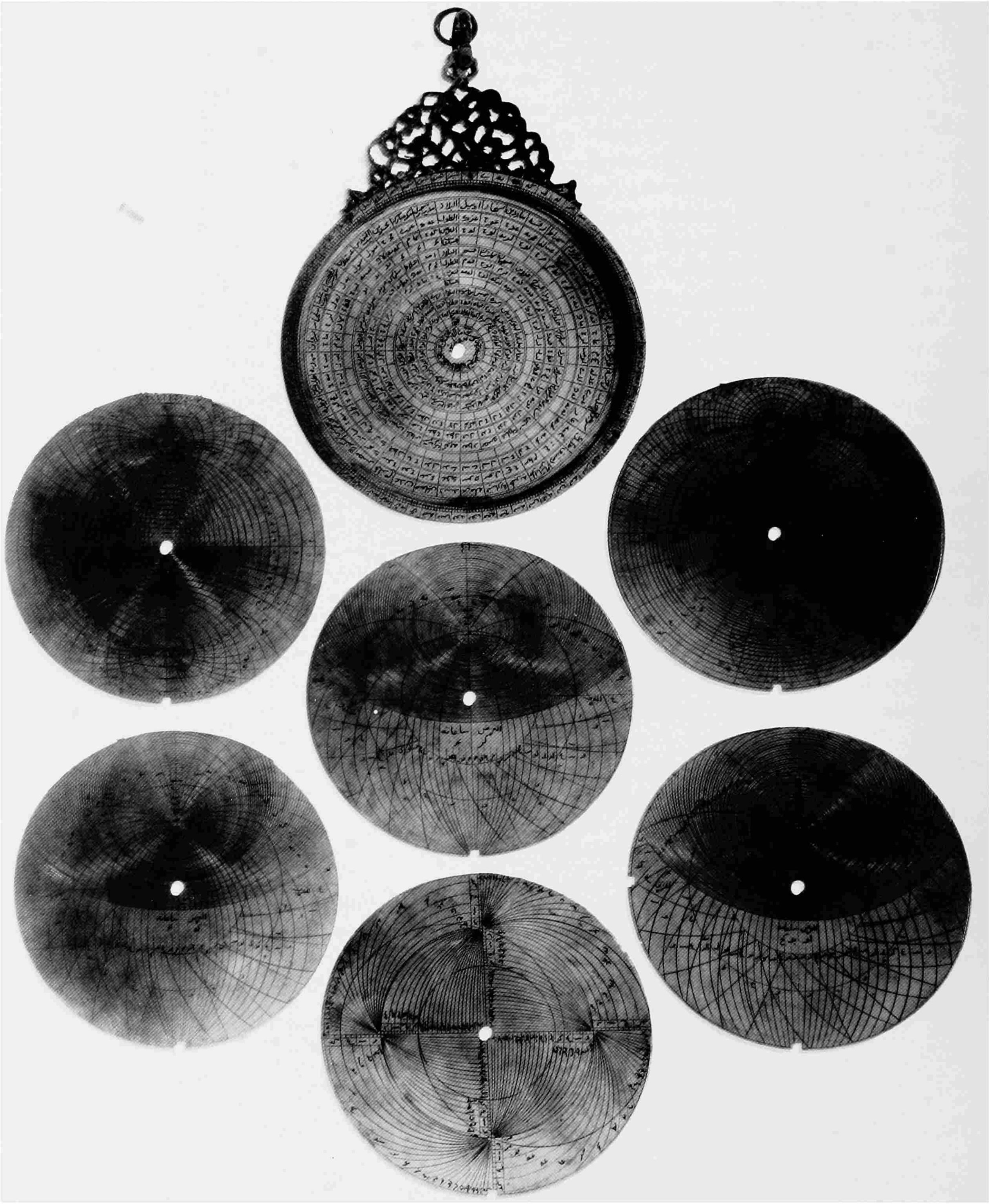


FIGURE 82.—Astrolabe No. 85. Front view of separate parts.

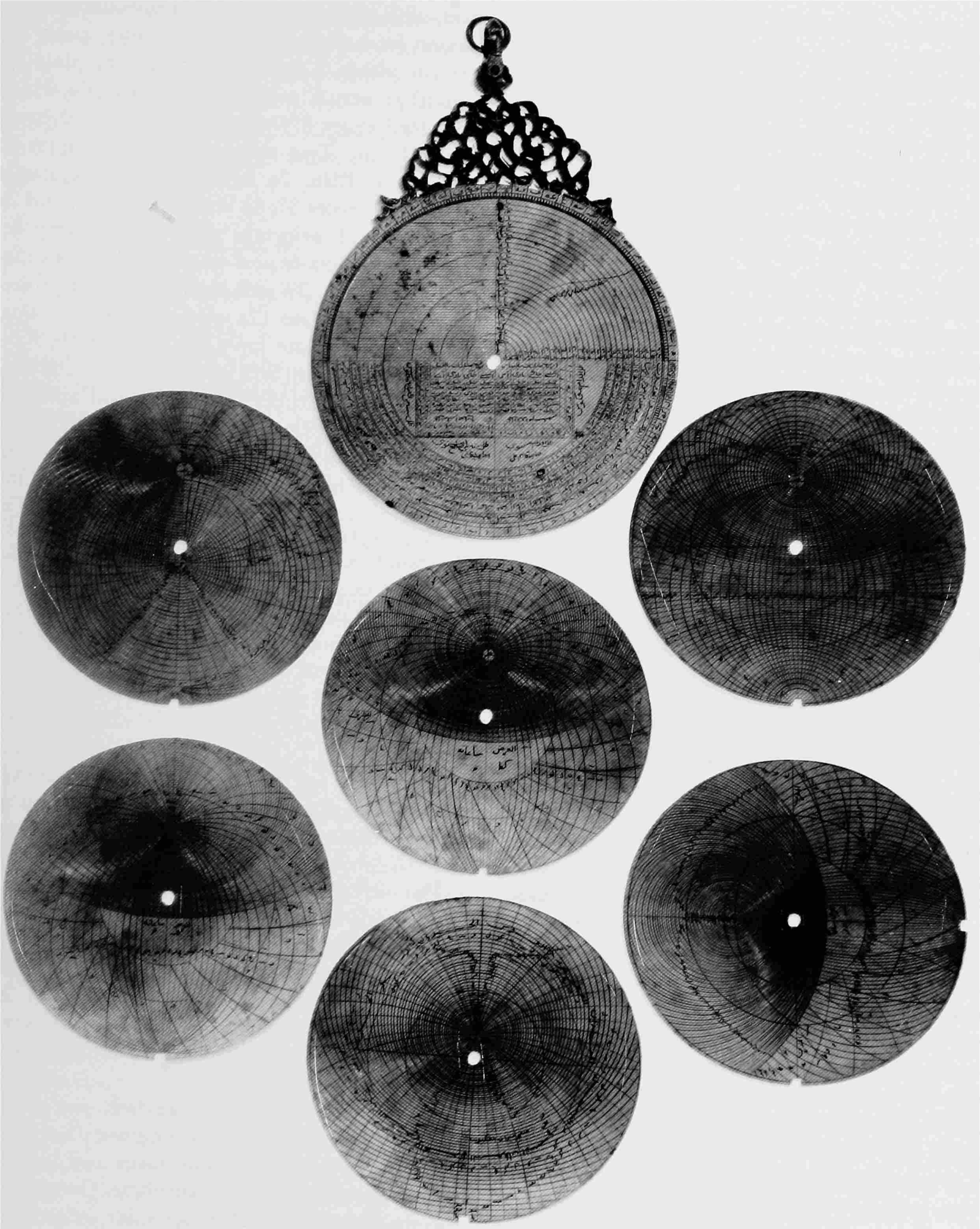


FIGURE 83.—Astrolabe No. 85. Back view of separate parts.

Diameter: 244 mm.

Material: Brass.

Characteristics: The throne is a pierced Moorish arch with six lobes and 44 holes, including a hole for the handle; decoration consists of embossed vines and flowers on a scored background. The stirrup-shaped handle has a diamond cross-section, as does the ring. The rim is divided into a scale of 360°. In addition to 5° and 1° subdivisions of this scale, there are also lines which subdivide each degree into thirds. The front central area is engraved with a gazetteer consisting of 91 recognizable place names (and two unknowns), along with latitude, longitude, and, in a few cases, length of daylight. The following phrase has been engraved in the center of gazetteer:

مالكه محمد تقى بن محب(؟)على قاينى
طمع كنيده (؟) بلغت خدا وغضب اله كرفتاد
شود.

It translates: "Its owner Muḥammad Taqi son of Muḥib [?] ʿAli Qaʾini [may it ward off the wrath of God]" (GS).

The back margin contains both altitude scales divided into degrees and cotangent scales (fingers left, feet right). Equally spaced arcs and a prayer line are engraved in the upper right quadrant; the upper left quadrant is divided by sines at sexagesimal intervals and by declination arcs contiguous with those in the upper right quadrant. Both lower quadrants contain shadow squares: tangent and cotangent scales divided sexagesimally on the left, and tangent and cotangent scales divided into feet on the right. A table of triplicities (Persian titles) has been engraved inside the box formed by the shadow square scales. a cartouche below the shadow squares is inscribed with the signature. Six semicircular tables fill the remaining area of the two lower quadrants: zodiacal signs, lunar mansions, planetary governors of terms, term divisions, planetary governors of faces, and face divisions. There are no engraved details or original markings on the edge of the instrument.

Of the six plates, three are engraved on both faces with the stereographic projection of the horizon for a single latitude, altitudes (every degree on plates 3 and 5, every 2° on plate 6), azimuths (every 6° except on plate face 6a, which is marked every 3°), unequal hours, and equal Italian hours. Two other plates are similar to these three. Plate 2a is marked with altitudes every 5°, 2b every 3°, 4a and 4b every 2°, and 2a is marked with azimuths every 5°, 2b every degree, and on faces 4a and 4b every 6°, except that one face of each (2b and 4b) has no hour projections, and one face (2a and 4a) has no equal Italian hours. (Plate faces 2b, 4a, and 4b, have coordinates for two latitudes.) Plate 1b contains only horizon, altitudes (every 2°), and azimuths (every 6°), and plate 1a contains parts of stereographically projected horizons for every degree of latitude. The horizon plate face also contains four declination scales subdivided into units of 6°. The plates are identified as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ṣafīḥa mīzān*	
	al-ʿankabūt	
2b	*ʿarḍ* 18	
	ʿarḍ 72	
3a	*li-ʿarḍ* 22	*sāʿātuhu* 13
3b	*li-ʿarḍ* 25	*sāʿātuhu* 13
4a	*li-ʿarḍ la*	
	ʿarḍ tisʿin	
4b	*ʿarḍ* 24	*sāʿātuhu* 13
	ʿarḍ kan(?) khafi (?)	
5a	*li-ʿarḍ* 27	*sāʿātuhu* 13
5b	*li-ʿarḍ* 29	*sāʿātuhu* 13
6a	*li-ʿarḍ* 32	*sāʿātuhu* 14 07
6b	*li-ʿarḍ* 36	*sāʿātuhu* 14 28

The pin holding the plates in the body is a bolt with a flat head. The wedge is a pin with a rectangular head.

Except for some Hindu-Arabic numerals designating equal hours on the plates, all inscription is Arabic Naskhi.

Remarks: Both rete and alidade are missing from this instrument. The engraver has made use of dotted lines on plate faces and in a few places on the body of the astrolabe. Only four of the spaces in the gazetteer set aside for length of daylight have been completed. Workmanship of varying quality is evident in the plates. On plate

6 the projections on the faces are displaced by 90° from the orientation of the projections on the other plates. Azimuths show signs of having been re-engraved on plates 2 and 4. A second astrolabe signed (and dated) by Qasim ᶜAli is in the History of Science Museum, Oxford, England, CCA No. 1219.

CCA No. 86

(FIGURES 84, 85)

Date: A.H. 1053 [1643].

Signature: ṣanaᶜahu Muḥammad Muqim ben ᶜIsa ben al-Hadad Asṭurlabi Hamayoni Lahori.

Components: Body, throne, handle, ring, five plates, rete, alidade, pin, and wedge.

Diameter: 144 mm.

Material: Brass.

Characteristics: The throne is basically triangular in shape, decorated with lobes and fillets. It is covered front and back with plates attached with rivets. The handle is stirrup-shaped; the ring is a corrugated circle. The rim is divided into four 90° scales. The front central area contains a gazetteer listing 77 places along with their geographic latitude and longitude. Diacritical marks are used throughout.

On the back of the astrolabe, the upper half of the margin contains two altitude scales. The lower half of the margin contains cotangent scales divided into feet (right) and fingers (left). Six equally spaced declination arcs divide the upper right quadrant. Two noon lines are graphed on these arcs. The upper is inscribed *khaṭṭ niṣf an-nahār li ᶜarḍ 27*; the lower is inscribed *khaṭṭ niṣf an-nahār li-ᶜarḍ 32*. Thirty equally spaced sines and cosines divide the upper left quadrant. Shadow squares divided into feet (right) and fingers (left) have been engraved in the lower quadrants. In the area bounded by these squares are two concentric semicircular tables: the outer is a table of zodiacal signs; the inner is a table of lunar mansions. The signature is inscribed inside the astrological tables; the date is inscribed below the shadow square.

Each of the five plates is notched at 270° Plate face 1a is inscribed with 32 stereographically projected horizons, one for every 2° between 4° and 66°. This face also carries scales which measure the degrees of arc between the projected equator and the tropics. On the back of this face is one which is divided only by stereographically projected altitudes (every 6°) and azimuths (every 10°). Eight other plate faces contain stereographically projected horizon, altitudes (every 6° or every 3°), azimuths (every 10° or every 6°), unequal hours, and equal Italian hours. Two of these (2b and 3b) also have equal Babylonian hours. The projections are identified as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ṣafīḥa mīzān al-ᶜanka[b]ūt*	
2a	*li-ᶜarḍ* 36	*sāᶜātuhu* 14
2b	*li-ᶜarḍ*	*sāᶜātuhu* 14
3a	*li-ᶜarḍ* 36	*sāᶜātuhu* 14
3b	*li-ᶜarḍ* 40	*sāᶜātuhu* 14
4a	*li-ᶜarḍ* 31	*sāᶜātuhu* 14
4b	*li-ᶜarḍ* 32	*sāᶜātuhu* 14 08
5a	*li-ᶜarḍ* 25	*sāᶜātuhu* 13
5b	*li-ᶜarḍ* 22	*sāᶜātuhu* 13

The rete pattern is comprised of trailing vines, trained to form a monogram inside the ecliptic. The ecliptic is rather crudely divided. Only one star name is legible; it is *Qalb al-ᶜAqrab* (at approximately 257° right ascension). The alidade is not counterchanged; it carries no inscription. Each sighting plate is pierced with a single hole. The pin is a bolt with hemispherical head and doorknob-shaped tip. the wedge is a small trapezoid.

The alphabet used by this maker is Arabic Naskhi.

Remarks: It is possible that the covers over the throne hide a delicate, pierced design characteristic of other astrolabes from Lahore. Certainly the use of dotted lines on the body and on the plates is consistent with this acknowledged origin. The plates on which these dotted lines are used to designate altitudes and azimuths (1, 3, 5) are notably more accurate than the two plates which use only continuous lines for these projections. These latter two plates, along with the rete and the alidade,

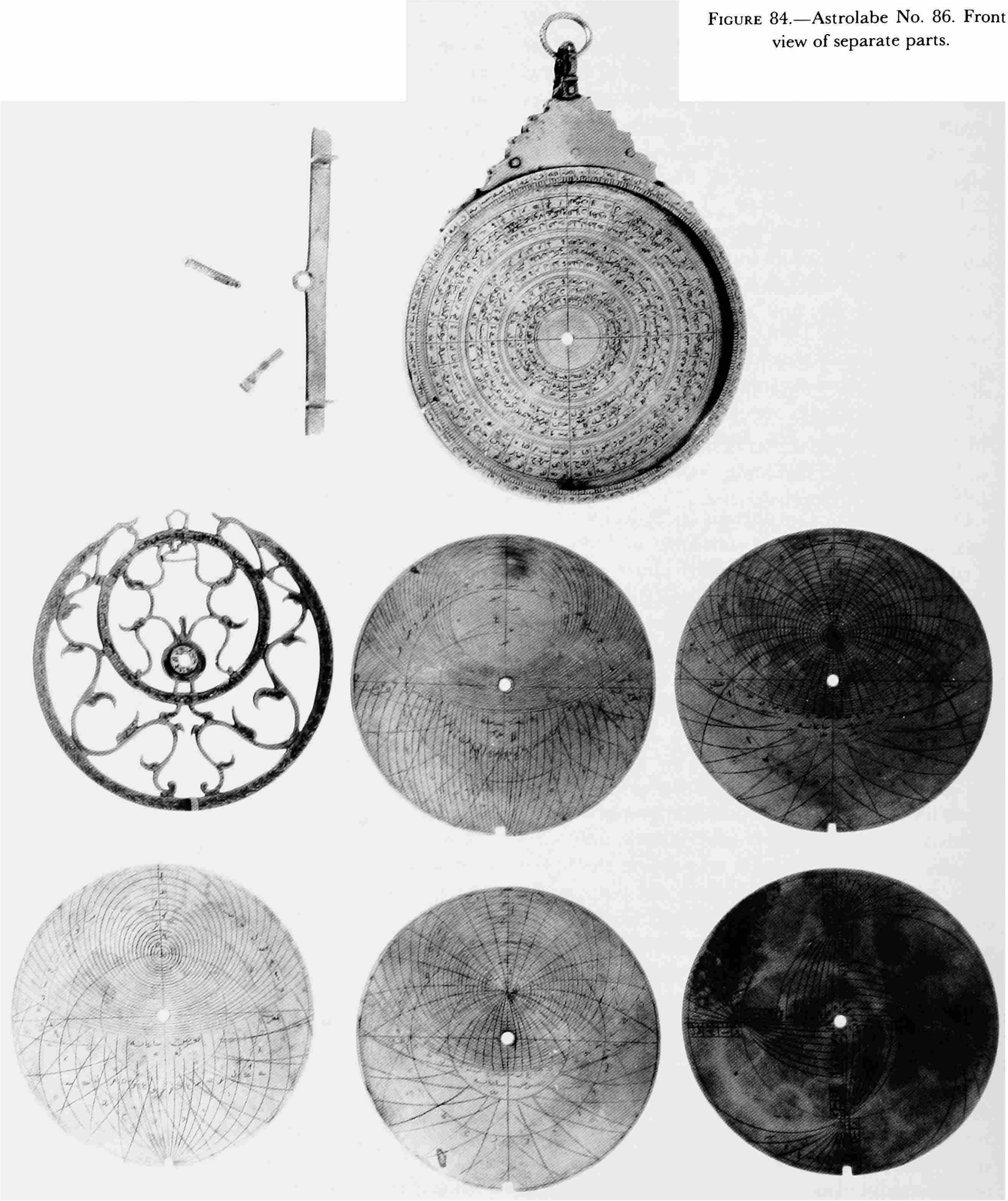
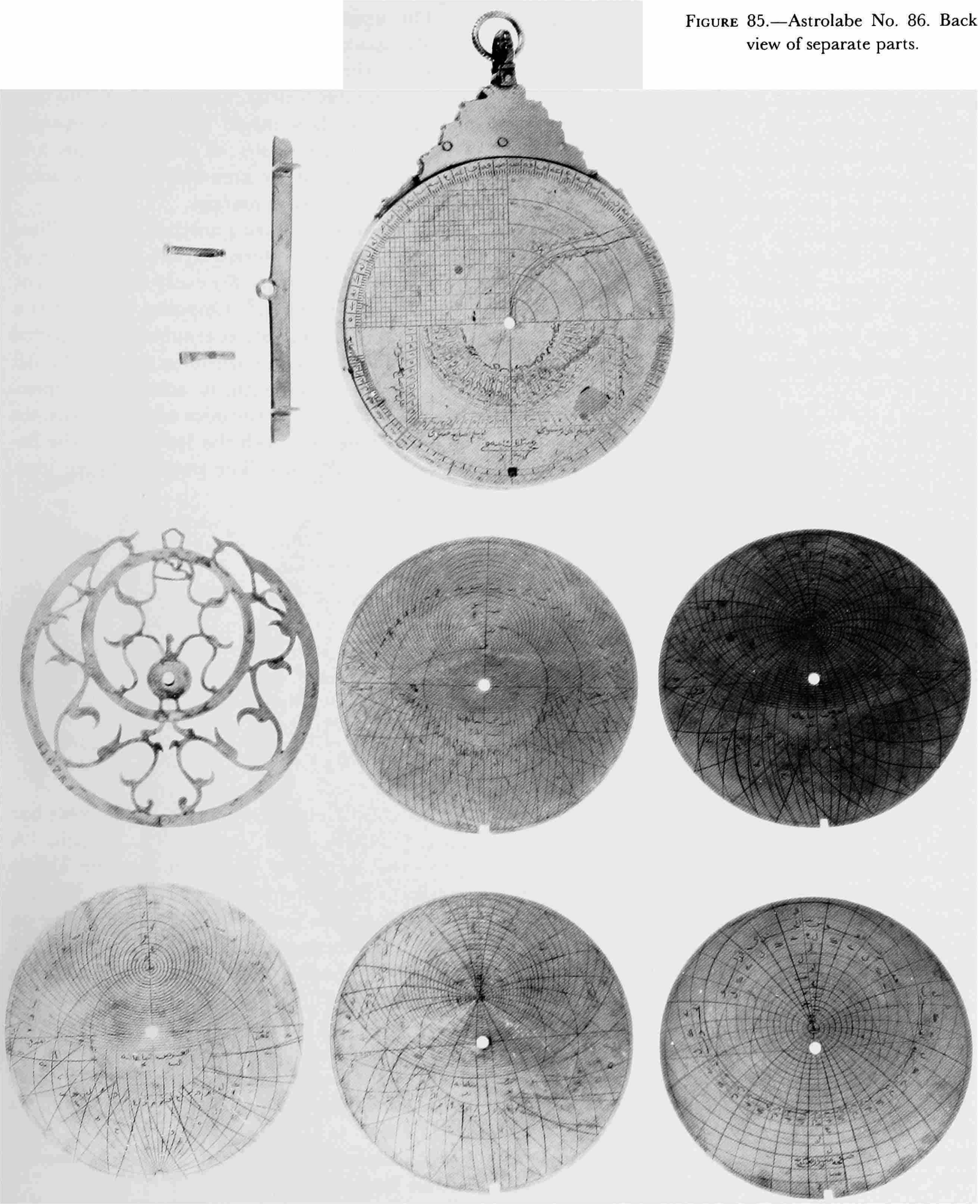


FIGURE 84.—Astrolabe No. 86. Front view of separate parts.

FIGURE 85.—Astrolabe No. 86. Back view of separate parts.



probably are not the work of Muḥammad Muqim. The rim scales measure both altitude (in the upper left and lower right quadrants) and zenith distance (in the upper right and lower left quadrants).

The *Computerized Checklist of Astrolabes* lists 24 other instruments by Muḥammad Muqim, including two on which he had collaborated with his brother Qaʾim Muḥammad (Nos. 69 and 3820). Examples of Muqim's work in the United States include an astrolabe in the Peabody Museum in Salem, Massachusetts (CCA No. 3655), and one at Yale University, New Haven, Connecticut (CCA No. 3807).

CCA No. 87

(FIGURES 23, 86, 87)

Date: A.H. 1070 [1659].

Signature: [ʿamal aqall al-ʿibad] Ḍiyaʾ al-Din Muḥammad ben Qaʾim Muḥammad ben Mulla ʿIsa ben Shaikh al-Hadad Asṭurlabi Hamayoni Lahori.

Components: Body, handle, ring, five plates, rete, alidade, pin, and wedge.

Diameter: 88 mm.

Material: Brass.

Characteristics: The throne is a pierced Moorish arch formed by intertwining vines. The stirrup-shaped handle has a rectangular cross-section. The ring has a lens-shaped cross-section. Four 90° arcs, each divided into units of 6° occupy the rim. There is a gazetteer in the front central area that lists 38 places along with the geographic longitude and latitude of each. The band of place means is introduced by the phrase *asmāʾ al-buldān.*

The upper half of the margin on the back of this astrolabe contains altitude scales divided into units of 6° and 2°. The lower half of the margin contains cotangent scales divided into feet (right) and fingers (left). The upper right quadrant contains a set of six equally spaced declination arcs. Two prayer lines have been graphed on these. The upper is identified *khaṭṭ niṣf an-nahār li-ʿarḍ* 27; the lower is identified *khaṭṭ niṣf an-nahār li-ʿarḍ* 32. The upper left quadrant is divided by 30 equally spaced sine lines. There are shadow squares in the lower quadrants divided into feet (right) and fingers (left). The signature and date are each inscribed inside the shadow squares. Two semicircular tables of zodiacal signs and lunar mansions fill the area between the shadow squares and the lower margin.

Each of the five plates is notched at 270°. Plate face 1a contains the stereographic projections of 32 quarter-horizons, one for every two degrees of latitude from 4° to 66°. Opposite this face is a face containing only stereographically projected altitudes (every 6°) and azimuths (every 10°). All other plate faces contain, in addition to stereographically projected altitudes and azimuths, the unequal hours and both the Italian and the Babylonian equal hours. The projections are identified as follows:

Plate	*Latitude*	*Length of daylight*
1b	*ṣafīḥa mīzān al-ʿankabūt*	
2a	*li-ʿarḍ* 36	*sāʿātuhu* 14
2b	*li-ʿarḍ* [?]	*sāʿātuhu*
3a	*li-ʿarḍ* 1	*sāʿātuhu* [?]
3b	*li-ʿarḍ* 32	*sāʿātuhu* 14 05
4a	*li-ʿarḍ* 22	*sāʿātuhu* 13
4b	*li-ʿarḍ* 24	*sāʿātuhu*
5a	*li-ʿarḍ* 18	*sāʿātuhu* 13 05
5b	*li-ʿarḍ* 20	*sāʿātuhu* 13 14[?]

The rete pattern incorporates a decorative bar and a bird's head inside the ecliptic. A symmetric pattern of vines connects the Tropic of Capricorn to the center of the rete. No star names have been inscribed. The division line on the ecliptic corresponding to the first point of Aries corresponds with 110° when the *muri* is aligned with 90°.

There are no counterchanges in the uninscribed alidade. A single hole above the fiducial line pierces each plate. The pin is a bolt with hemispherical head. The wedge is a rectangle.

The alphabet employed by the maker is Arabic Naskhi.

Remarks: The obvious difference in quality between the body of this astrolabe and the

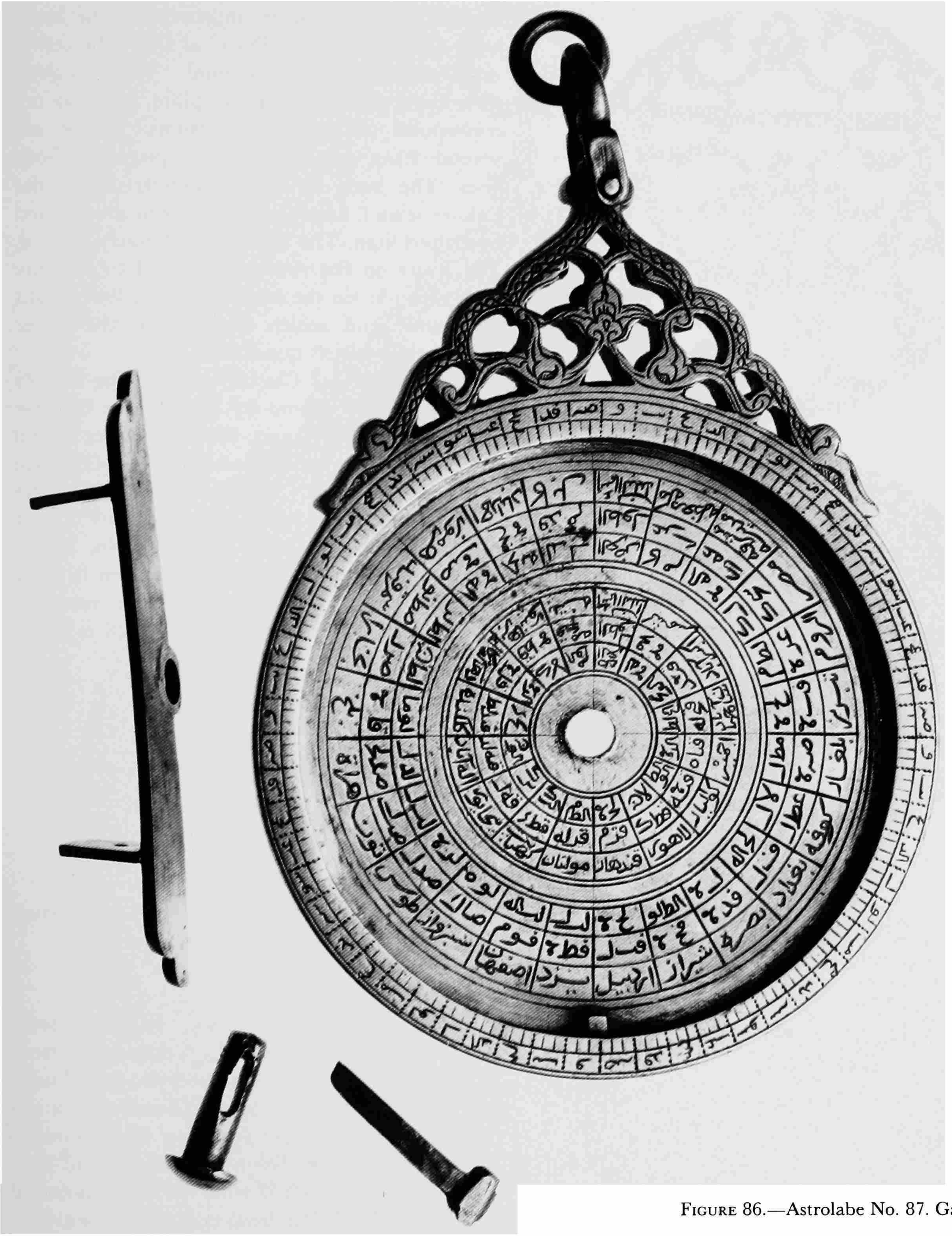


FIGURE 86.—Astrolabe No. 87. Gazetteer.

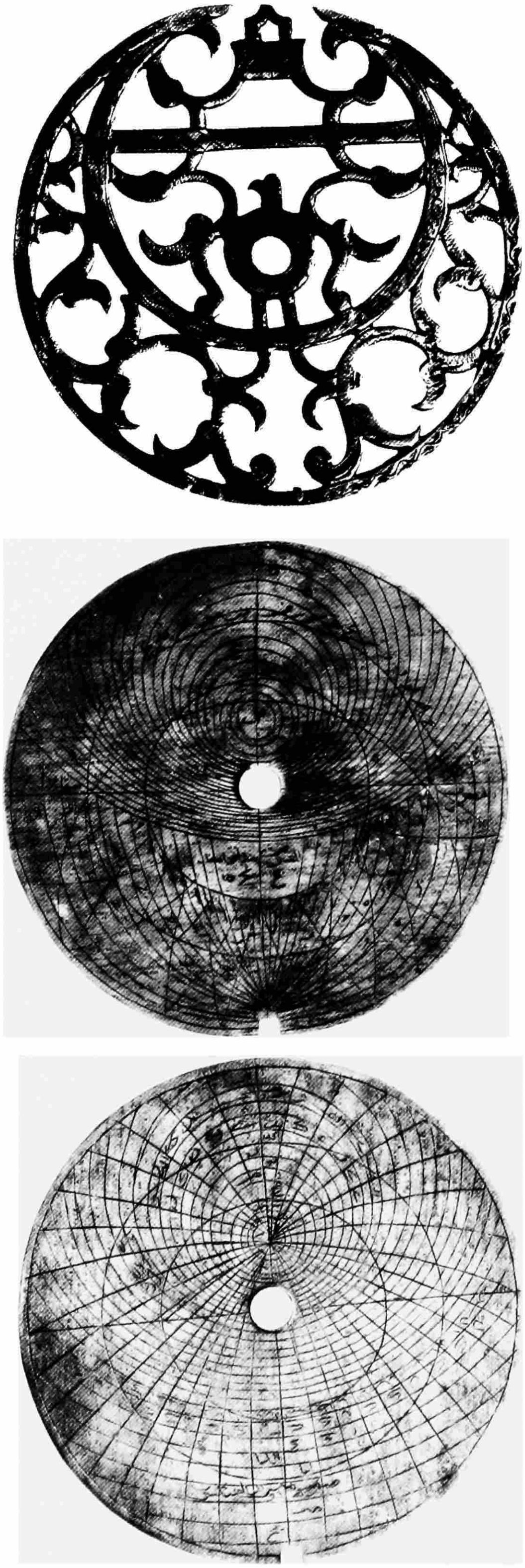


FIGURE 87.—Astrolabe No. 87. *ʿAnkabūt* with plates.

various separable parts suggests that the latter were not the works of Ḍiyaʾ al-Din. The rete is unquestionably nonfunctional. The numbers identifying altitudes on the plate faces do not correspond to specific divisions. There are several stray arcs among the projected hour lines. The body is itself characteristic of the Lahore school. Many of its divisions are marked by dotted lines. The throne is delicately pierced. The scales on the rim can be used to measure both altitude (in the upper left and lower right quadrants) and zenith distance (in the upper right and lower left quadrants).

The *Computerized Checklist of Astrolabes* lists 25 other astrolabes signed by Ḍiyaʾ. Five of these are in the United States, including three in the collection of the Adler Planetarium in Chicago: one dated A.H. 1047 [1637] (CCA No. 2558), one dated A.H. 1057 [1647] (CCA No. 1095), and one dated A.H. 1071 [1660] (CCA No. 2554). The example in the Brooklyn Museum in New York (CCA No. 3555) is undated; the example in a private collection (CCA No. 3809) is dated A.H. 1073 [1662].

CCA No. 88

(FIGURES 35, 88, 89)

Date: Ca. A.D. 1750.

Signature: See "Remarks."

Components: Body with throne, handle, ring, five plates, rete, alidade, pin, and wedge.

Diameter: 159.5 mm.

Material: Brass.

Characteristics: The high, Moorish arch-shaped throne is pierced in a symmetric pattern and decorated with an engraved vine and flowers and leaves. The stirrup-shaped handle has a rectangular cross-section. The ring has a double-lunate cross-section. The rim is divided into 360°. The last unit is marked with the *abdjad* numeral signifying "360." The front central area was prepared to accommodate a gazetteer of 70 place

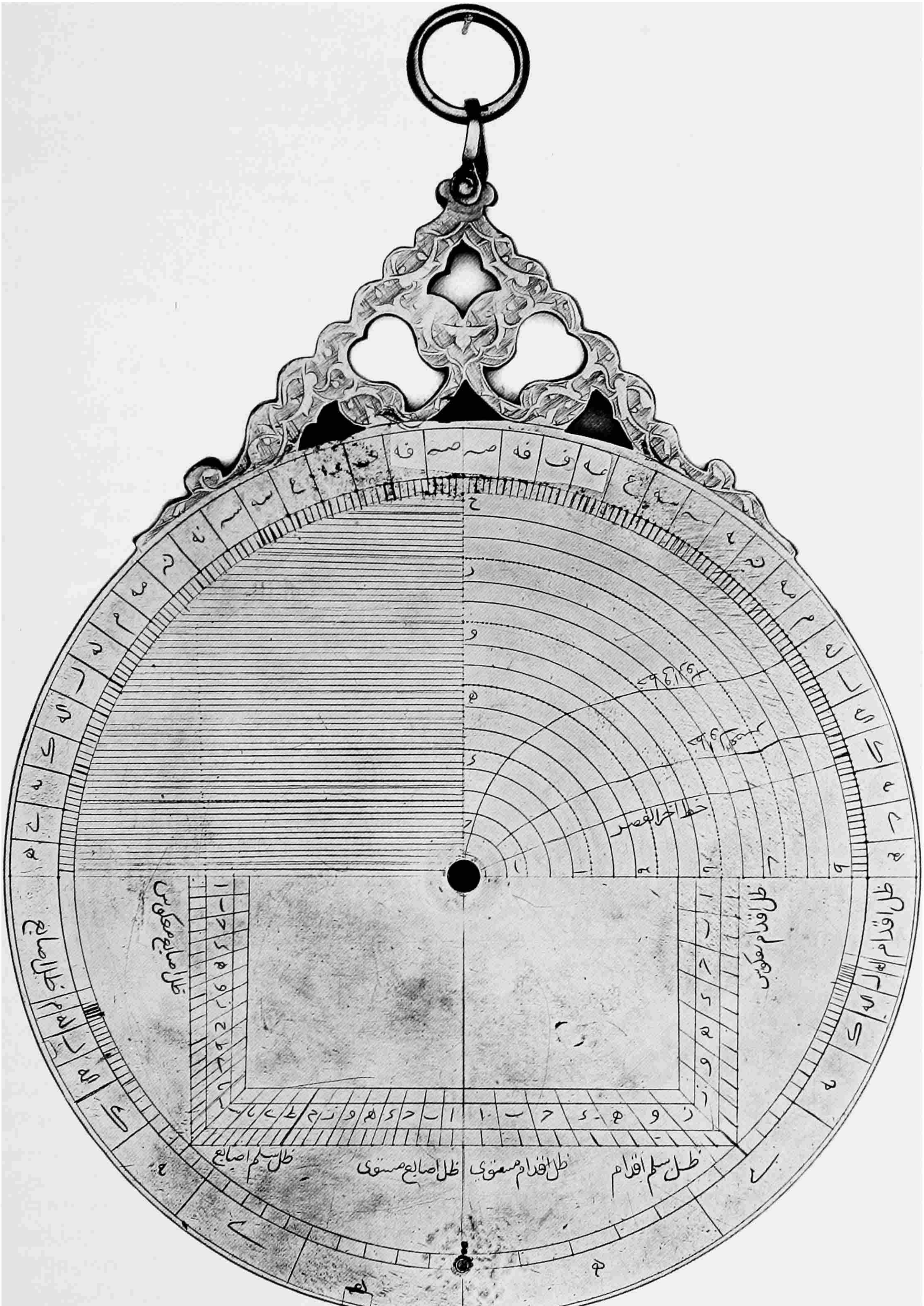


FIGURE 88.—Astrolabe No. 88. Back view.

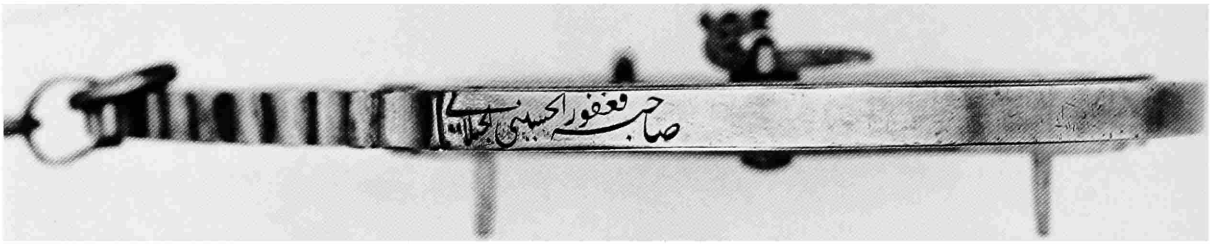


FIGURE 89.—Astrolabe No. 88. Inscribed edge.

names. Only 47 places are listed, however, along with the latitude and longitude of each.

On the back of this astrolabe, the upper margin is divided by altitude scales. The lower margin contains cotangent scales divided into fingers (left) and feet (right). The upper right quadrant contains an equally spaced declination scale. Lines representing the beginning and end of the prayer *al-*^{c}*aṣr* and the sunset line are graphed onto these declination arcs. Sixty sine lines divide the upper left quadrant. There are shadow squares divided into fingers (left) and feet (right) in the lower quardrants.

One of the five plates is notched at 0°, 90°, 180°, and 270°. One face of this plate contains the projections of quarter-horizons for every 2° of latitude between 4° and 66°. This same plate face contains four obliquity scales subdivided into units of 6° and ending at 23°30′. Remaining plates are notched only at 270°, and remaining plate faces each contain a stereographically projected horizon reference frame for a single latitude. On plate face 4b this network consists only of a horizon, altitudes (every 6°), and azimuths (every 10°); the zodiacal signs are also named on this face. Plate face 1b contains only horizon, altitudes (every 5°), azimuths (every 10°), and unequal hours. All other plate faces contain horizon, altitudes (every 3°), azimuths (every 10°), unequal hours, equal Italian hours, and equal Babylonian hours. the inscription on the plate faces reads as follows:

Plate	*Latitude*	*Length of daylight*
1b	^{c}*arḍ* 30	
2a	^{c}*arḍ* 21 40	*sā*^{c}*ātuhu* 13 21
2b	^{c}*arḍ* 25	*sā*^{c}*ātuhu* 13 35
3a	^{c}*arḍ* 27	*sā*^{c}*ātuhu* 13 44
3b	^{c}*arḍ* 31 50	*sā*^{c}*ātuhu* 14 8
4a	^{c}*arḍ* 36 00	*sā*^{c}*ātuhu* 14 30
4b	*mīzān al-*^{c}*ankabūt*	
5a	^{c}*arḍ* 38 00	*sā*^{c}*ātuhu* 14 42
5b	^{c}*arḍ* 45 00	*sā*^{c}*ātuhu* 15 28

The relatively symmetric pattern of the rete of this astrolabe is formed by twining vines. There is a complete, counterchanged (once) equinoctial colure. The ecliptic band is subdivided into units of 6° There are 31 inscribed star pointers; on them a small dot marks the part of the flower which represents the star. Circles have been engraved on the back of the rete. One arm of the alidade contains divisions corresponding to the placement of the declination arcs in the upper right quadrant. Divisions corresponding to the sine scale have been inscribed on the other arm. A single small hole pierces the sighting plates. The pin is a bolt with a hemispherical head. There is a washer functioning as a ringlet. The wedge is shaped like and decorated to resemble a horse's head.

The inscription is Arabic Naskhi.

Remarks: The pierced throne, relatively fragile rete, division of cotangent scale, and content of gazetteer all suggest that this instrument is of Indian origin. It is unusually thick (9.5 mm). No latitude is given for which the prayer lines in the

upper right quadrant would be appropriate. The sine scale has been carelessly inscribed, but the other workmanship appears to be of good quality. The rete is in excellent condition. The alidade appears to have been cast in one piece.

A name, Ṣaḥibuhu Maghfur al-Ḥusayni al-Jilani, has been engraved on the edge of this astrolabe near the top. Since the hand is different from that of the other inscription on the astrolabe, it seems likely that the name identifies an owner rather than a maker.

CCA No. 144

(FIGURES 25, 90)

Date: A.H. 704 [1304].

Signature: Aḥmad ben Ḥusain ben Baṣo.

Components: Rim with throne riveted to backplate with throne, handle, ring, ten plates, rete, alidade, pin, and wedge.

Diameter: 166.5 mm.

Material: Brass.

Characteristics: Both front and back faces of the throne are engraved with the details of trifid flowers. Three holes, in addition to a handle hole, pierce its Moorish arch-shaped form. The handle is a stirrup with a diamond cross-section. The ring also has a diamond cross-section. The rim is engraved with a scale of 360°. The engraved lines in the front central area essentially constitute a stereographic projection of altitudes and azimuths for latitude 90°. Altitudes are projected every 6°; azimuths, every 10°.

The outer margin of the back contains two altitude scales in the upper portion and two cotangent scales in the lower portion. A scale of the zodiacal signs follows the perimeter of the quadrant area just inside the outer margin. An eccentric calendar scale borders the quadrant area just inside the zodiac scale. The vernal equinox (Aries, 0°) on the latter scale coincides with the date 14.5 March on the former. A scale of unequal hours has been engraved in the upper left quadrant. The signature and date are inscribed in the upper quadrants. Two shadow squares, both graduated into finger units, fill the lower quadrants.

Each of the ten plates includes a tooth. On eight of the plates and on the body the inscription is in Kufic script of the maghribi type. Of the 16 faces on these plates, 9 (1b, 3a, 3b, 4a, 4b, 5a, 5b, 6a, and 6b) contain stereographically projected horizon, altitudes (every 6°), azimuths (every 10°), unequal hours, and prayers: plate 10b contains only horizon, altitudes, and azimuths (every 6°); five (8a, 8b, 9a, 9b, and 10a) contain horizon and houses; 1a contains only horizons and altitudes (every 6°). The plates are identified with the following inscriptions:

Plate	*Inscription*	
1a	*li-jāmiʿ al-ʿurūḍ*	
1b	*ʿarḍ Gharnāṭa wa kull balad ʿarḍuhu*	37 30
3a	*ʿarḍ Mecca wa kull balad ʿarḍuhu*	21 40
3b	*ʿarḍ Iskandaria wa kull balad ʿarḍuhu*	31
4a	*ʿarḍ Marākesh wa kull balad ʿarḍuhu*	30
4b	*ʿarḍ Fās wa kull balad ʿarḍuhu*	33
5a	*ʿarḍ Sinna* [?] *wa kull balad ʿarḍuhu*	35 20
5b	*ʿarḍ al-Jazīrah wa kull balad ʿarḍuhu*	34 30
6a	*ʿarḍ al-Ria*[?] *wa kull balad ʿarḍuhu*	36 30
6b	*ʿarḍ Malagha wa kull balad ʿarḍuhu*	37
8a	*ʿarḍ*	36 30
8b	*ʿarḍ*	33
9a	*madhhab al-Ghafūr ʿarḍ*	37 30
9b	*madhhab Baṭlamyūs*[?] *ʿarḍ*	37 30
10a	*madhhab Hermes ʿarḍ*	37 30
10b	[no identifying inscription]	

Two of the plates are inscribed in Arabic Naskhi script. Of the four faces on these, one (2a) is blank and three contain stereographic projections of horizon, altitudes (every 6°), azimuths, unequal hours, and prayers. The projections are located as follows:

Plate	*Inscription*	
2b	*ʿarḍ al-Madīna al-Munawwarah wa kull balad ʿarḍuhu*	24
7a	*ʿarḍ Qusṭanṭīniyah wa kull balad ʿarḍuhu*	41
7b	*ʿarḍ Adrina wa kull balad ʿarḍuhu*	42

The rete of the astrolabe incorporates 27 star pointers, each consisting of a pierced ball or trefoil base and a hook pointer. An engraved star name

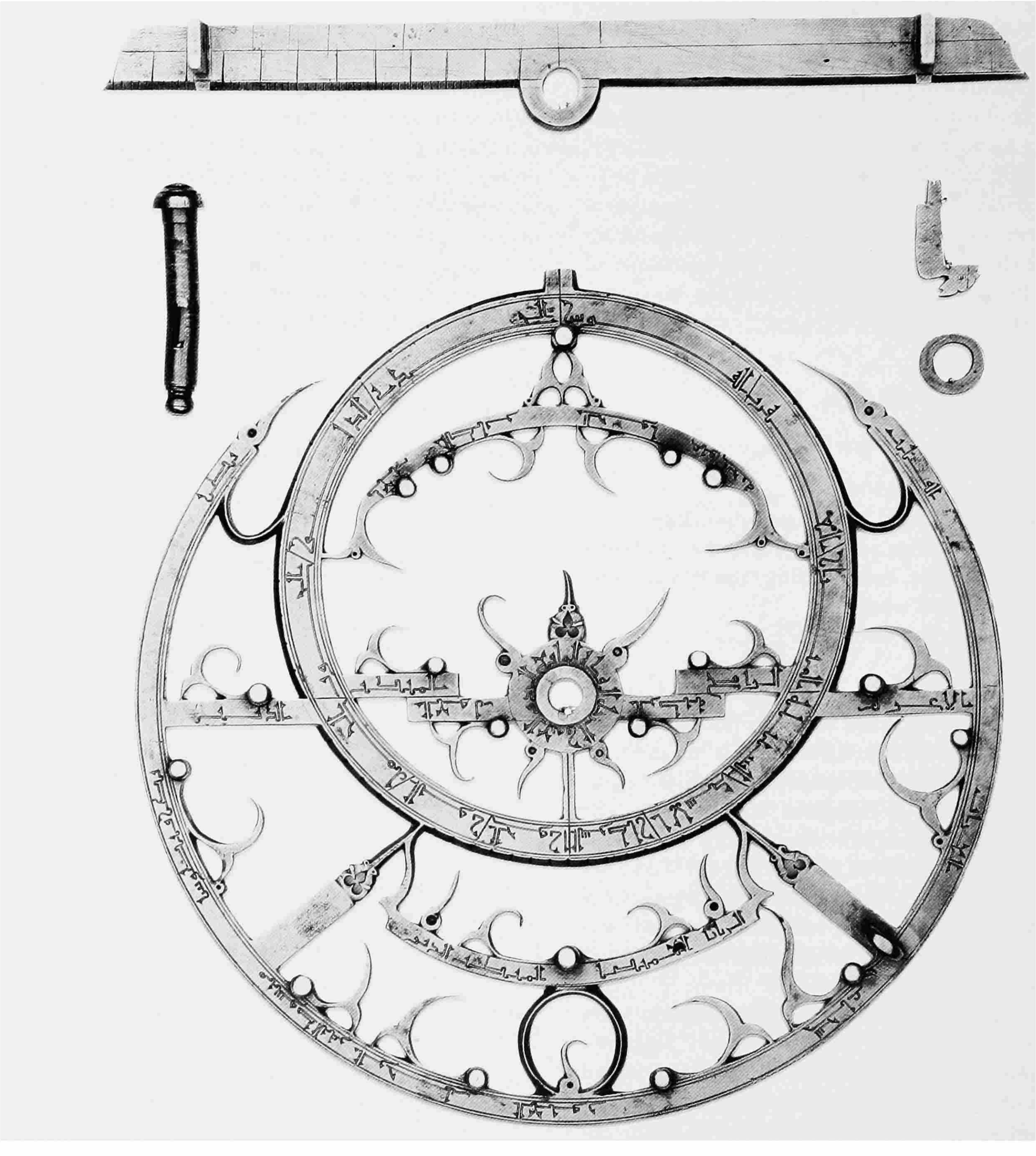


FIGURE 90.—Astrolabe No. 144. ᶜ*Ankabūt* and alidade.

can be identified with each pointer. The ecliptic is subdivided into 6° units. The alidade has a central semicircle and half brackets at the ends of its arms. Its beveled fiducial edge is not interrupted by counterchanges. One arm of the alidade is divided by 60 (along fiducial line) and 12 equally separated lines and by 5 lines separated by unequal distances. No numbers or letters appear on these scales. The boltlike pin has a semicircular head and a doorknob-shaped tip. The wedge is shaped like a bird with a long beak. Eyes and headfeathers have been engraved on the basic shape.

Remarks: Two black depressions on either side

of the handle hole may have been holes, which were filled in. The third month on the calendar scale is spelled *Mars.* On the shadow squares, a single designation *aẓ-ẓill al-mabsūṭ* extends below both tangent scales. On two plates, the line of morning prayer is designated *qaws ash-shafaq.* On one of these, both the afternoon and the evening prayer are also so designated. The metal of the two plates engraved in Naskhi script is not as highly polished as that of the other plates. It is unlikely that these plates are the work of Aḥmad ben Ḥusain.

The Aḥmad signature appears on three other astrolabes: CCA No. 132 dated A.H. 664 [1265] and now in the Reale Academia de Historia, Madrid; CCA No. 1080 dated A.H. 704 [1304], now in the Società Ligure de Storia Patria; and CCA No. 1203 dated A.H. 709 [1309], now in a private collection in Europe.

CCA No. 186

(FIGURES 11, 26, 91)

Date: Ca. A.D. 1475 (see "Remarks").

Signature: None.

Components: Body with throne, handle, ring, six plates, rete, alidade, pin, wedge, and index.

Diameter: 105 mm.

Material: Brass.

Characteristics: The uninscribed *armilla fixa* has Moorish affinities. Engraved leaves decorate the front. The handle is stirrup-shaped with diamond cross-section. The ring has an oval cross-section.

The outer circular band on the rim is divided by a scale of 24 hours. The inner circular band is divided by scales of 360° composed of units of 5° and 1°. Stereographically projected tropics and equator are the only engraved lines on the front central area.

The outer margin of the back contains four altitude scales (one in each quadrant). The circular band inside these scales is divided by a zodiacal scale. An eccentric calendar scale is engraved just inside the zodiacal scale. The vernal

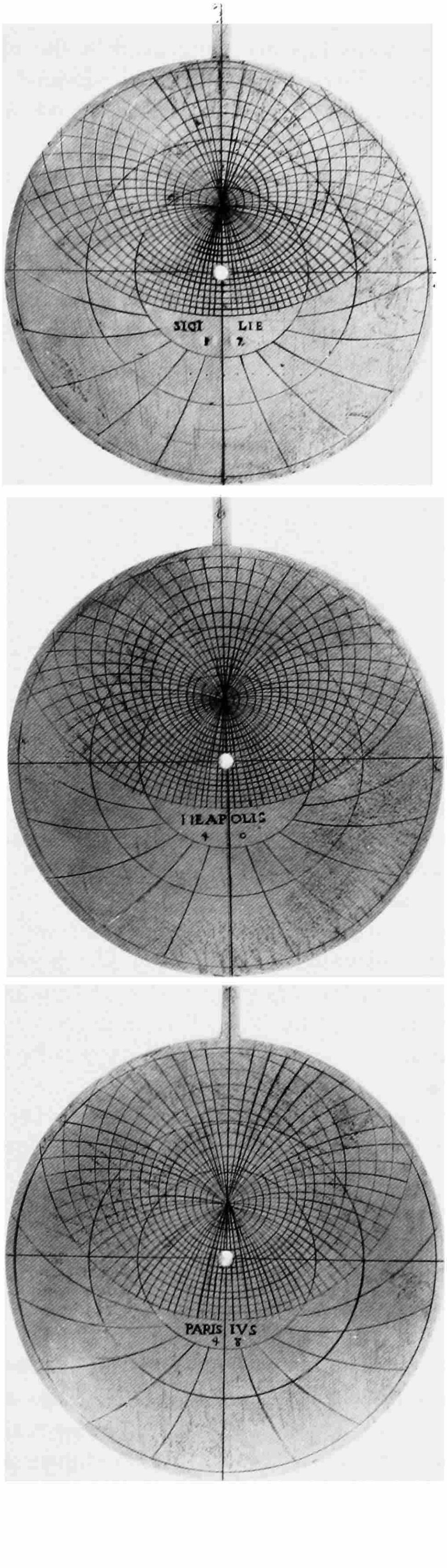


FIGURE 91.—Astrolabe No. 186. Plates for latitudes 37°, 40°, and 48°

equinox corresponds to 10.5 March. A scale of unequal hours has been engraved in the upper quadrants. Two shadow squares (divided into finger units) have been engraved in the lower quadrants. The inscription is Latin.

Four of the six plates have a tooth at 90°. Plate 6 has a notch at 90°; plate 5 has neither tooth nor notch. Each plate face is engraved with the stereographic projection of horizon, altitudes (every 5°), azimuths (every 5°), and unequal hours. The altitudes and the unequal hours are identified with inscribed numerals only on plate 5a. Each face is inscribed as follows:

Plate	*City*	*Latitude*
1a	Sicilie	37
1b	Emed	35
2a	Alexandrie	31
2b	Damascum	33
3a	Venetie	45
3b	Parisius	48
4a	Neapolis	40
4b	Tvnini	38
5a	Castelli	43
5b	Roma	42
6a	Prvgis	52
6b	Rotomagvs	50

The rete design incorporates a complete counterchanged east-west bar, a partial counterchanged meridian, and upper and lower equinoctial arcs. Twenty flame-shaped star pointers are inscribed with the Latin names of stars. One uninscribed star pointer is shaped like an anthropoid stick figure. The ecliptic circle is subdivided into units of 10° and 1°. Three of the star names are engraved on the backs of their respective pointers.

The alidade is counterchanged about the center. It has a beveled fiducial edge and diagonal ends. Each sighting plate is pierced with two holes; the lower hole is larger. The pin is a cylinder with a hemispherical head. The wedge is shaped like a pin with a head. The index arm is radial with beveled edges and a pointer near the center.

Remarks: The numerals identifying the unequal hours 10, 11, and 12 on the scale of the back of this astrolabe are mirror images of the correct numerals. The anthropoid figure incorporated into the rete appears to point to the star γ Bootis. The right ascension of α Leonis is 141° The assumed date is based on information conveyed by the zodiacal calendar and the rete.

CCA No. 204

(FIGURES 92, 93, 94)

Date: A.D. 1548.

Signature: I Galois.

Components: Body and throne plate, handle, ring, rete, alidade, pin, wedge, and index arm.

Diameter: 150 mm.

Material: Brass.

Characteristics: The throne is shaped like a high crown. On the back it has been inscribed with the word "MIDI." The stirrup-shaped handle includes decorative disks at the ends of the crossbar.

The margin of the front face of the body plate is divided by five concentric circular scales. The outermost of these is a wind-circle with 12 divisions inscribed, "*MERIDIES* / LIBO*NOTVS / APHRICVS* / *OCCIDENS* / CHORVS* / CIRCIVS* / *SEPTENTRIO* / BOREAS* / VVLTVRNVS* / *ORIENS* / EVRVS* / EVRO*AVSTER." Next innermost is a scale of 24 equal hours inscribed with Hindu-Arabic numerals as two scales of 12 hours. Next is an uninscribed scale of 360° marked at intervals of 1°. Next is an uninscribed scale of 72 5° units. The innermost marginal scale measures altitude; it consists of 72 inscribed 5° units. The front central area contains the stereographically projected horizon coordinates for latitude 48°. Projected lines include horizon (inscribed at left, "P. PRIMA HORA DIEI" and on the right, "PRIMA HORA NOCTIS"), altitudes (every 3°), azimuths (every 10°), houses (12), and unequal hours.

The marginal scales on the back of the astrolabe include (from outermost to innermost) an uninscribed scale of 360° marked in 1° units, a scale of zodiacal degrees marked in units of 5°, a zodiacal scale, an uninscribed scale of 366 days, an inscribed scale of day-groups, and a scale of months. The vernal equinox corresponds to 10.5

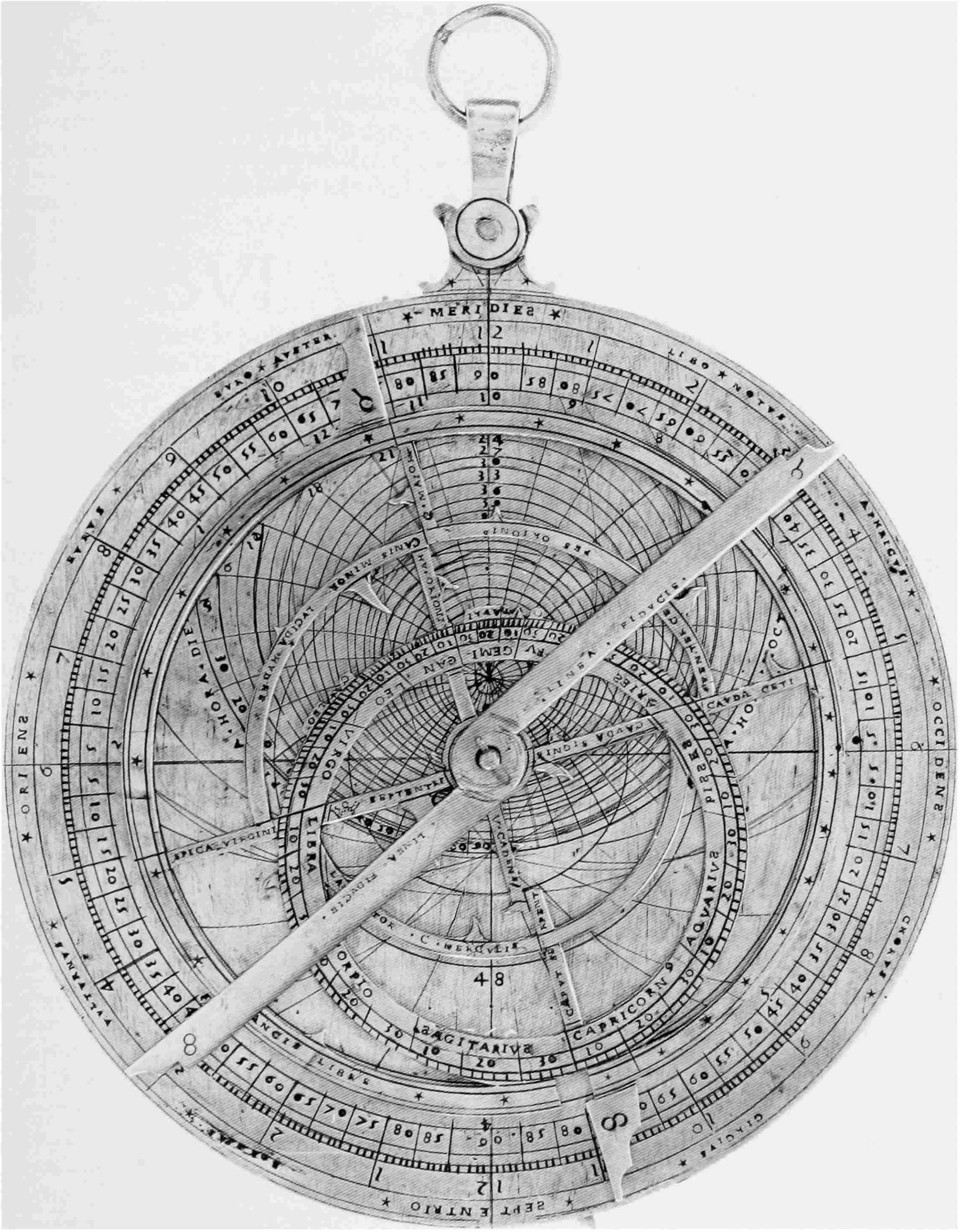


FIGURE 92.—Astrolabe No. 204. Front view.

March. A semicircular table (giving the sign of the zodiac, the mediation [see page 56], the name, the magnitude, and the declination of 20 stars) and shadow squares (divided into units of fingers) have been engraved in upper and lower quadrants. The signature and date are inscribed below the shadow squares.

The rete is a simple design, incorporating a

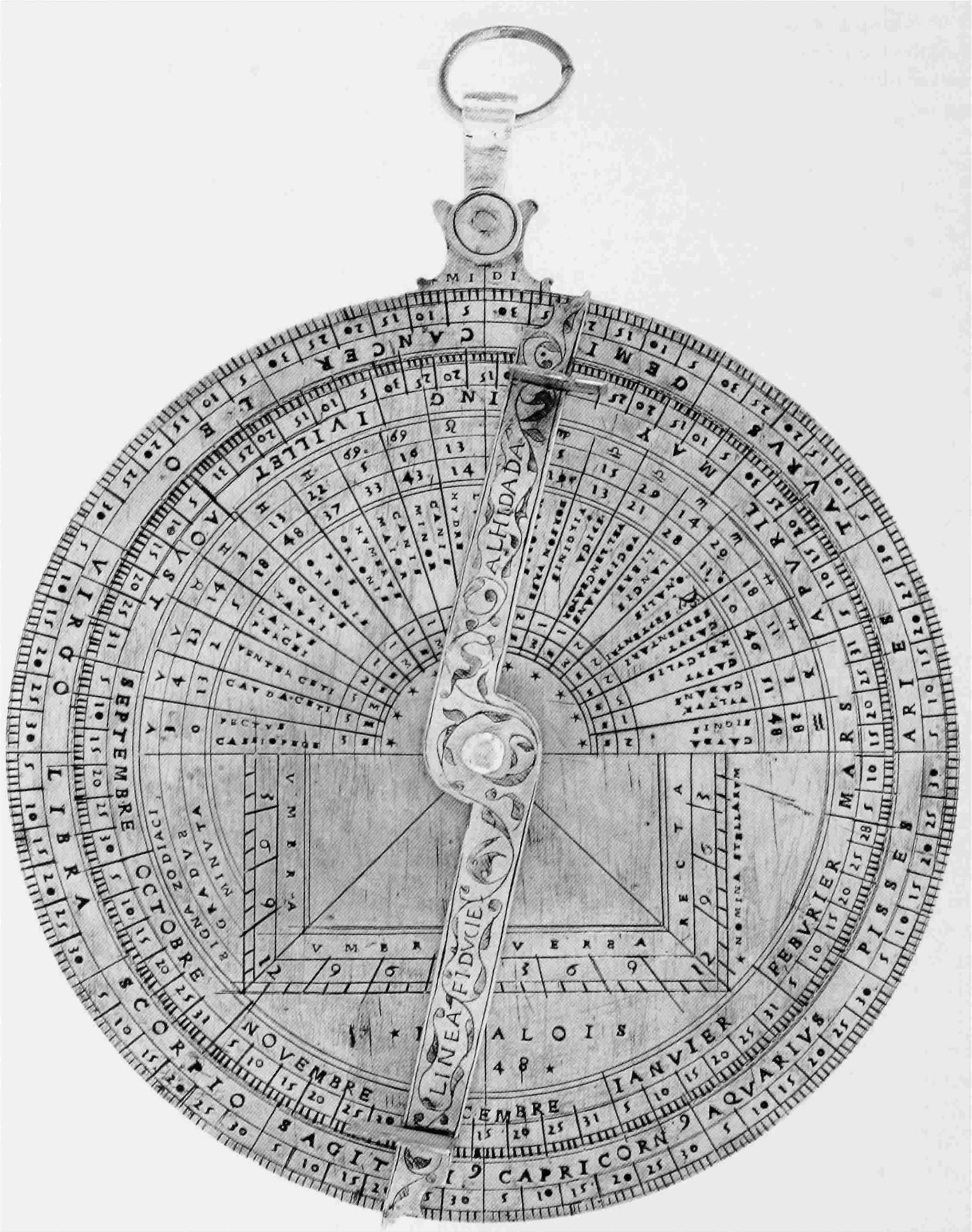


FIGURE 93.—Astrolabe No. 204. Back view.

complete equator and complete solstitial and equinoctial colures. An "8" has been engraved at 270° on the Capricorn band; a "Q" has been engraved at 90°. There are 20 flame-shaped star

FIGURE 94.—Stöffler's table of fixed stars, including parameters identical to those inscribed on the back of Astrolabe No. 204. This rendition appears on folio 17 verso of *Elucidatio Fabricae Ususque Astrolabii* (Oppenheym, 1512).

cto. L. Et nota equatoris & vbi regula tangit diametrum. f. h. pinge punctū: & emitte pedem vnum circini alio in centro. e. stante in hoc punctum: & circino non variato verte pedem mobilem in lineam occultam & imprime notam que proposite stelle centrum aut cacumen manifestat. Quam nomine & magnitudine exornabis. Consimiliter age cum alijs stellis tabule. Imponendo cuilibet signo duas aut plures stellas.

TABVLA STELLARŪ FIXARŪ

continens earum longitudinem ſm celi mediationem declinationes: partes & magnitudines earundem.

Nomina Stellarum fixarum Latina.	Arabica	Signa Zodiaci.	Celi mediatio. G	M	Declinatio. G	M	Pars Declinatōis	Magnitudo
Stella polaris:	Alrukaba.	♈	1	15	85	51	S	3
Pectus Cassiopeie.	Scheder	♈	3	0	53	45	S	3
Vmbilicus Andromade	Mirach.	♈	10	43	34	13	S	3
Venter Ceti.	Batakaytos.	♈	23	2	12	39	M	3
Cauda Ceti.	Deneb kaytos.	♈	4	31	20	26	M	3
Dextrum latus persei.	Algenib.	♉	14	5	47	42	S	2
Caput algol.	Ras algol.	♉	11	20	39	32	S	2
Pleiades.	Athoraye.	♉ ♉	20 20	33 54	22 21	36 54	S S	5 5
Naris ceti.	Menckar.	♉	11	23	2	18	S	3
Hircus.	Alhaiot.	♊	11	21	44	56	S	1
Oculus Tauri.	Aldebaran.	♊	3	18	15	55	S	1
Dexter Humerus Orionis	Bed algeuze.	♊	22	37	6	16	S	1
Sinister pes Orionis	Rigel algeuze.	♊	13	48	9	14	M	1
Caput Gemini antecedentis.	Ras algeuze.	♋	14	0	32	28	S	2
Caput Gemini sequentis.		♋	16	49	28	43	S	2
Canis maior.	Alhabor.	♋	5	33	15	49	M	1
Canis minor.	Algomeisa.	♋	16	43	6	9	S	1
Cor Leonis et dicitur rex.	Kalb eleced	♌	22	11	14	19	S	1
Ceruix Leonis.		♌	24	49	22	19	S	2
Lucida Hydre.	Alphard.	♌	13	14	4	32	M	2
Dorsum Vrse maioris.	Dubhe.	♍	5	19	62	36	S	2
Cauda Leonis	Deneb eleced.	♍	19	16	17	9	S	1
Dorsum Leonis.		♍	19	30	22	51	S	2
Principiū caude Vrse maioris.	Alioth.	♎	7	17	58	7	S	2
Mediū caude Vrse maioris.		♎	15	30	57	24	S	2
Extremū caude Vrse maioris	Benenatz.	♎	22	57	51	42	S	2
Vociferans vel Lancreator.	Alramech.	♎	29	21	21	45	S	1

pointers, 18 of which are identified with Latin inscriptions. The ecliptic is divided into 180 units of 2° and 36 units of 10°. The alidade is counterchanged about its center. The words "LINEA FIDVCIE" and "ALHIDADA" are engraved on the arms. The index is complete, counterchanged about the center, and inscribed with the words "LINEA FIDVCIE" on each arm. An "8" has been engraved on one arm of the index; a "Q" on the other. A rivet serves as pin. The wedge is in its simple form.

Remarks: There are a number of clues embodied in this instrument which indicate that the maker consulted an edition of Johannes Stöffler's *Elucidatio Fabricae Ususque Astrolabii.* The scales and projection on the front of this instrument are similar to those Stöffler describes and illustrates. But the most convincing clue can be found on the back of the work marked "I. Galois." The parameters in Galois's table of star names are exactly those given in Stöffler's "Tabulae stellarum fixarum." Nineteen of the entries come from Stöffler's table giving the mediation or *mediationem* for certain stars; one entry comes from Stöffler's table giving stellar longitude.[106] The 20 stars listed on the back of Galois's astrolabe are the same stars incorporated into Galois's rete.

There are some errors in the calendar scale: six day divisions between 19 April and 26 April; six day divisions between May 19 and May 26; five day divisions between 24 December and 1 January. The engraver has employed both a Gothic "4" and a sixteenth-century "4" in inscriptions on this instrument.

The marks "8" and "Q" on the rete and the moveable index resemble the symbols used to indicate conjunction (Q) and opposition (8) in astrology and astronomy.

No other instruments are known to have been signed by Galois.

CCA No. 221

(FIGURES 14, 32, 34, 95)

Date: A.D. 1542.
Signature: M.P.

Components: Rim, backplate, throne, handle, ring, four plates, rete, alidade, pin, wedge, and index arm.
Diameter: 207 mm.
Material: Brass.
Characteristics: The triangular throne is formed by two symmetric scrolls topped by a disk. The stirrup-shaped handle has a revolving attachment for holding the ring.

The outer band of the rim is divided by a scale of 24 equal hours (numbered 1 to 24 in Hindu-Arabic numerals). The inner band is divided by four altitude scales. In between these bands is a band divided into 360 equal parts. The front central area is blank.

Marginal scales on the back include a band of four altitude scales, a band divided into 360 equal parts, a band containing the 5° subdivisions of a zodiacal scale, and a band containing 12 equal divisions, each identified with a zodiacal symbol. Inside the zodiacal scale is an eccentric calendar scale, the months inscribed in Latin. The vernal equinox coincides with 10.5 March. The upper right quadrant contains a scale of unequal hours. The upper left quadrant contains a scale of equal hours constructed for use at a latitude of approximately 48°15′ (Munich?). Shadow squares divided into finger units are engraved in the lower quadrants. The initials of the maker and the date have been inscribed below these squares.

All four plates have a tooth at 90° Except for one (1a) which has only a series of stereographically projected horizons, all plate faces have horizon, altitudes (every 2°), azimuths (every 10°), houses (seven to twelve), and unequal hours. These latter conventional plate faces are inscribed with the following latitudes:

Plate	*Latitude*
1b	36
2a	41
2b	43 30
3a	45
3b	47
4a	49
4b	51

The rete has an east-west bar that is counterchanged twice, and the lower half of a meridian

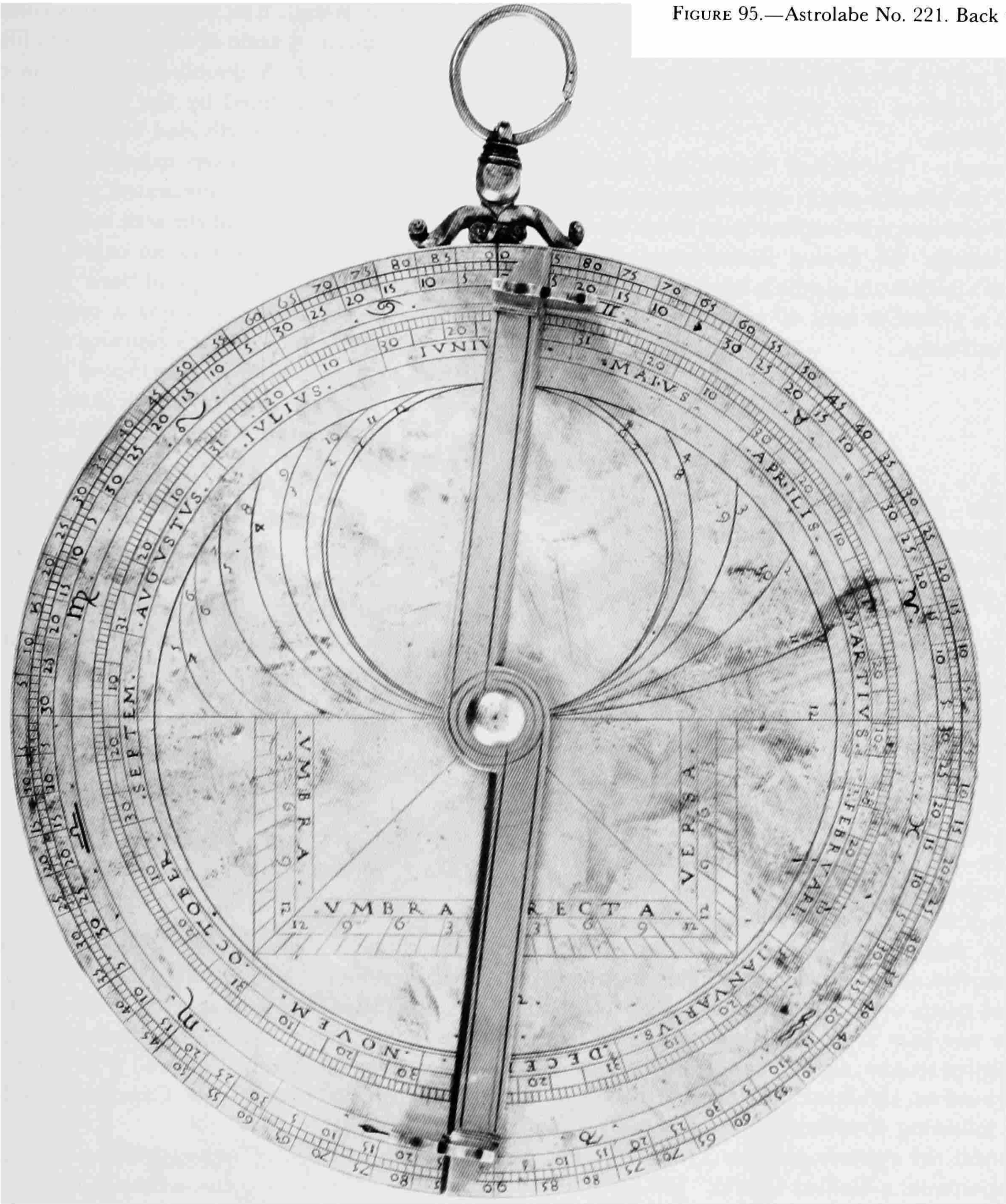


FIGURE 95.—Astrolabe No. 221. Back view.

bar. The remaining strapwork consists of intersecting arcs of circles. There are 21 flame-shaped star pointers. Each of these is inscribed with a Latin star name, sometimes in combination with a zodiacal symbol. The ecliptic is subdivided into units of 2° and 10°. There are no markings on the back of the rete.

The sighting plates of the counterchanged alidade are each pierced by a slit above a hole, both in the plane of the fiducial edge. The pin is

cylindrical with a flat head. The wedge is a rectangle. The radial index arm has a beveled edge and a curved bracket design at the outer end, similar to that which decorates the ends of the alidade.

Remarks: The initials "M.P." are characteristic of the Munich clock- and compass-maker Markus Purmann, who marked some of his work with his initials. All known instruments with Purmann's initials are sundials, however, and all date from a period at least 40 years after the date on this astrolabe.

CCA No. 262

(FIGURES 12, 96, 97, 98)

Date: MDXXXVII [or A.D. 1537].

Signature: Georgivs Hartman Norenberge.

Components: Body with throne, handle, ring, four plates, rete, alidade, pin, wedge, and index arm.

Diameter: 160 mm.

Material: Brass.

Characteristics: The throne is a triangle, composed of three disks and decorated with the details of rosettes. The ends of the axle of the stirrup-shaped handle are decorated with rosettes. The ring has a circular cross-section.

The relatively wide rim of this instrument contains three different circular scales. The 12 divisions of the outermost scale are inscribed with the Latin names of the winds. Roman numerals (identified as two groups of 12 hours) mark off 24 equal hours on the next band. Inside the hour scale are four altitude scales. Stereographically projected tropics, equator, and colures have been engraved on the front central area. In addition, the following inscribed phrase is barely visible between the equator and the Tropic of Cancer: "Appartenne a Galileo Galilei;" just outside the Tropic of Capricorn at 270° there has been engraved a small "12."

Three different circular scales divide the margin of the back. These include a set of four altitude scales (outermost circle), a zodiacal scale with 5° subdivisions identified with Roman numerals (middle bands), and a concentric calendar scale (inner band). The vernal equinox coincides with 10 March. A scale of unequal hours fills the upper quadrants. A double-headed eagle decorates the circle defined by the sixth-hour lines. Two shadow squares, divided into fingers, have been engraved in the lower quadrants. The area inside the left square is decorated with an eagle with a human head. Half the area inside the right quadrant is decorated with an eagle; the other half is decorated with diagonal bars.

Each of the four plates has a tooth at 90°. Every plate face (except 3b) contains at least the following stereographically projected lines: horizon and altitudes (every 2°). Five plate faces also contain stereographically projected azimuths (every 10°), unequal hours, and houses. On plate 3a, only equal Italian hours supplement the basic projection. On plate 4a, the basic projection is supplemented by azimuths (every 10°), houses, and by both unequal hours and equal Italian hours. Plate face 3b is badly scratched; it contains no projected lines. The projections are identified with the following inscriptions:

Plate	*Latitude*		
1a	LATITV	GRA	XLVIII
1b	LATITV	GRA	XLV
2a	LATITV	GRA	LIIII
2b	LATITV	GRA	LI
3a	[no inscription]		
4a	LATITV	GRA	XLII
4b	LATITV	GRA	XXXIX

In addition to the identifying inscription along the meridian between the equator and the Capricorn circles, the degrees of latitude for each face have been engraved in Hindu-Arabic numerals on the tooth. A small "12" has been engraved just outside the Capricorn circle on faces 1b, 2b, and 3b.

The rete design incorporates a multiply counterchanged (six times) east-west bar. Other structural supports are made up of strings of arcs. The star pointers are 27 pierced bulbar sickles. Each is identified with a Latin inscription. The ecliptic circle is subdivided into units of 6°. The ecliptic divisions and the Capricorn circle have been engraved on the back of the rete; a small "12" has been engraved at 270°.

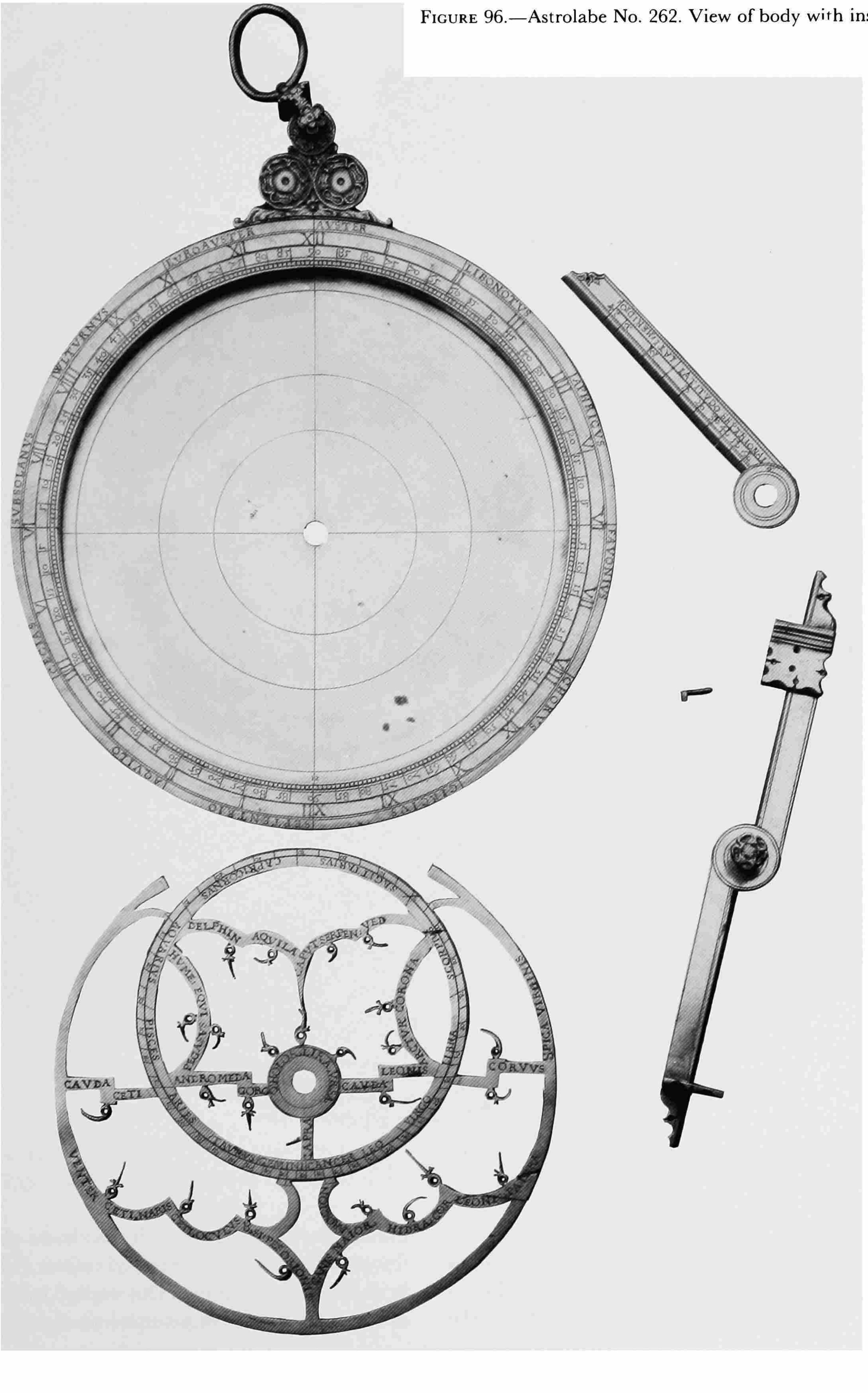


FIGURE 96.—Astrolabe No. 262. View of body with inscription.

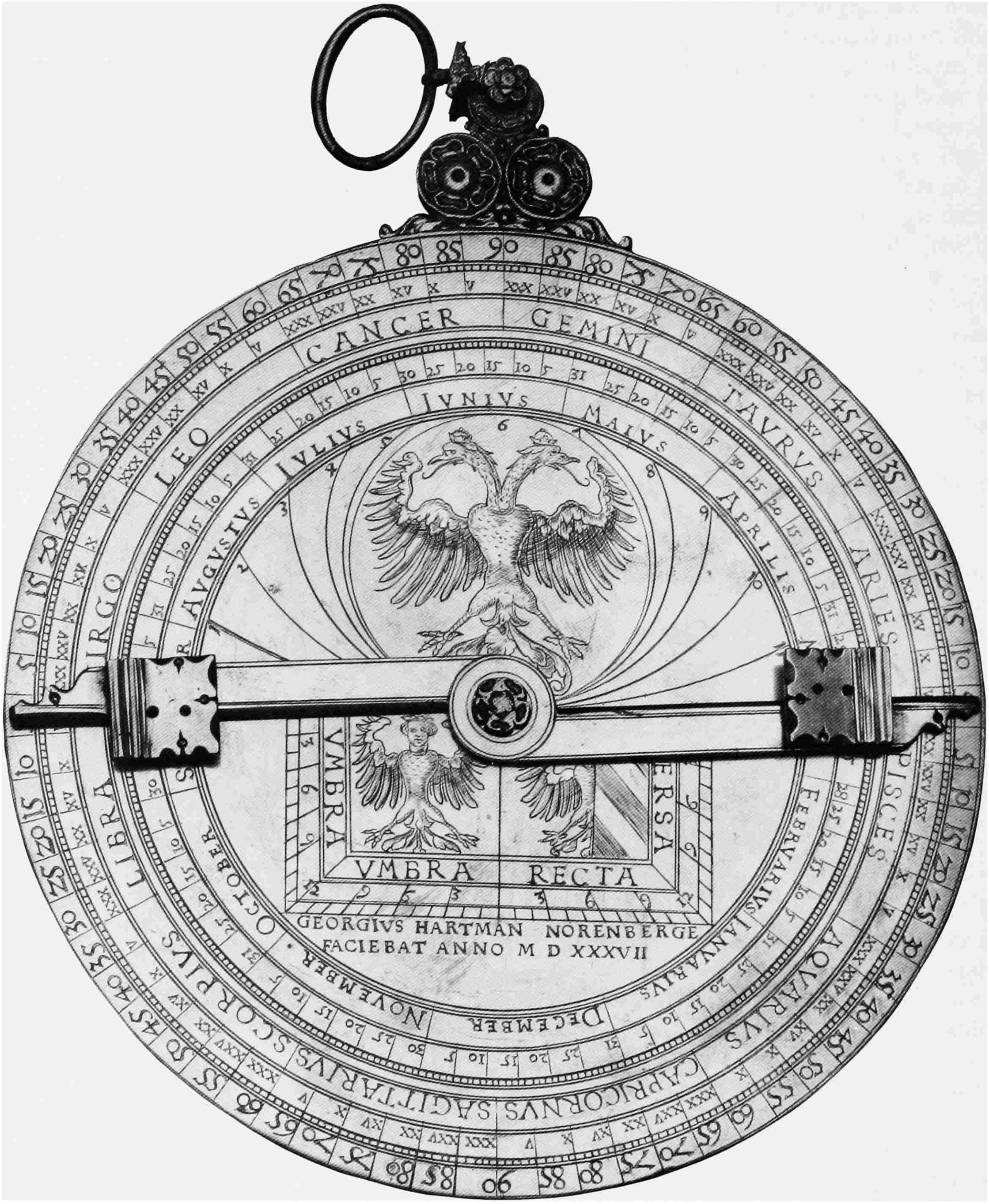


FIGURE 97.—Astrolabe No. 262. Back view.

The alidade is counterchanged about the center. Its sighting plates collapse; each is pierced with two holes in the plane of the beveled fiducial edge. A small "12" has been engraved on the underside. The pin is a bolt, the head of which is decorated with a five-petalled rosette. The wedge is shaped like a pipe. The radial index arm is divided by a scale of celestial declination. A leaf

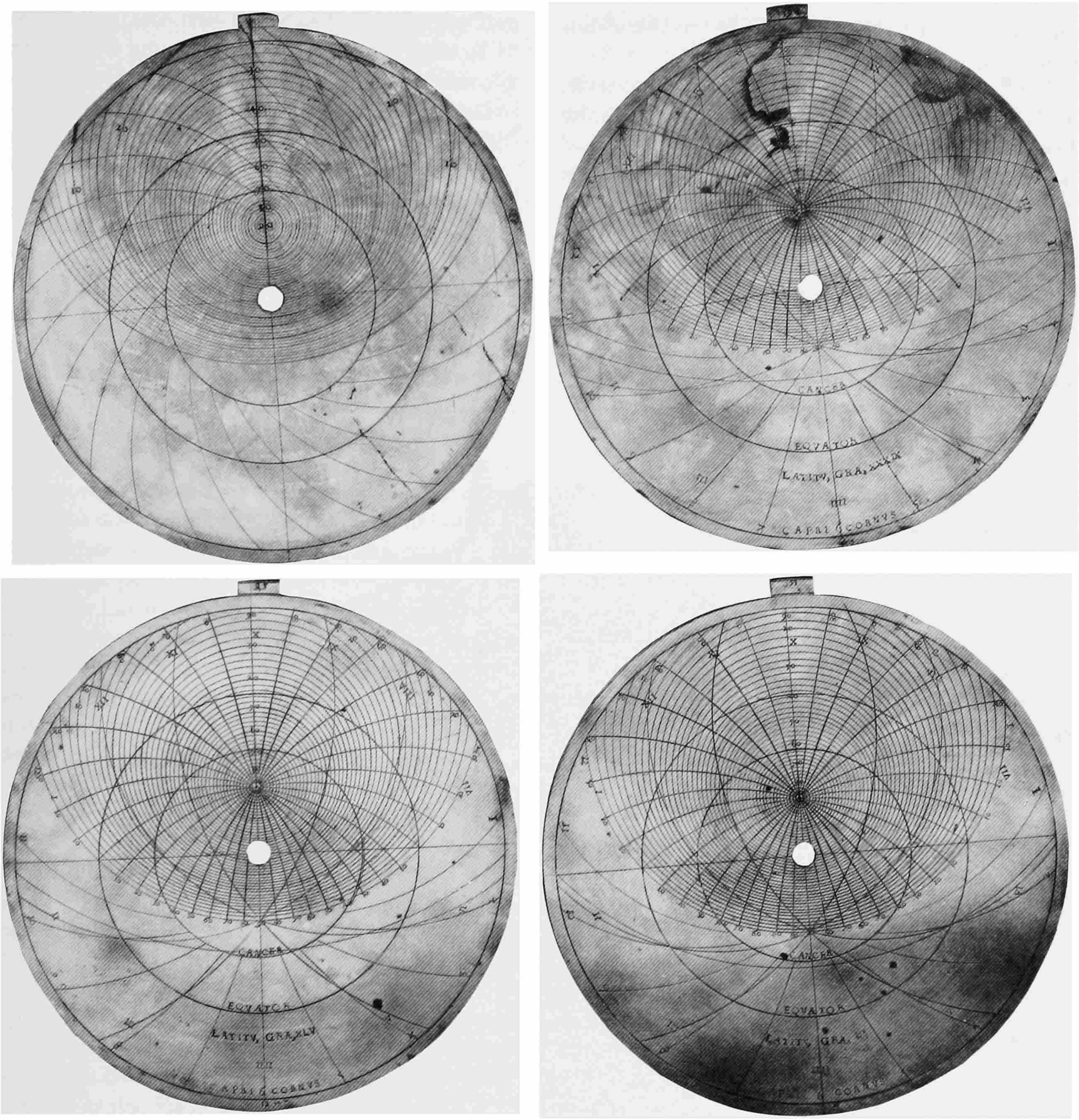


FIGURE 98.—Astrolabe No. 262. A plate without identifying inscription (upper left) is compared with plates for 39°, 45°, and 51°

design decorates its end. A small "12" and some straight lines have been engraved on the underside.

Remarks: Surviving examples of Georg Hartman's work indicate that he made at least 22 astrolabes in the period between A.D. 1525 and 1548. All of these, except a gilt example preserved in the Rijksmuseum voor de Geschiedenis det Naturwetenschappen in Leyden and a paper example preserved in the Museum of the History of Science in Oxford, are made of brass. Other Hartman astrolabes in collections in the United States include one dated 1537 (CCA No. 3035) at Yale University in New Haven, Connecticut, and

one dated 1540 (CCA No. 267) in the Adler Planetarium in Chicago.

Hartman's astrolabes have a distinctive style, and this example is typical. The inscription in the front central area relating to Galileo is in a hand different from that used to inscribe the rest of the instrument. The functional inscription and the signature can be traced to the sixteenth century. The sixteenth-century Dürer "4" used on some scales is a telling bit of evidence. The lines engraved on the back of the rete and on the back of the index arm may be interpreted as construction guidelines.

CCA No. 304

(FIGURES 15, 99)

Date: Ca. A.D. 1450.

Signature: See "Remarks."

Components: Rim with throne attached to backplate with throne, handle, ring, rete, alidade, pin, wedge, and index.

Diameter: 145 mm.

Material: Brass.

Characteristics: The *armilla fixa* is a simple design consisting of three lobes. The ends of the bar of the stirrup-shaped handle are decorated with

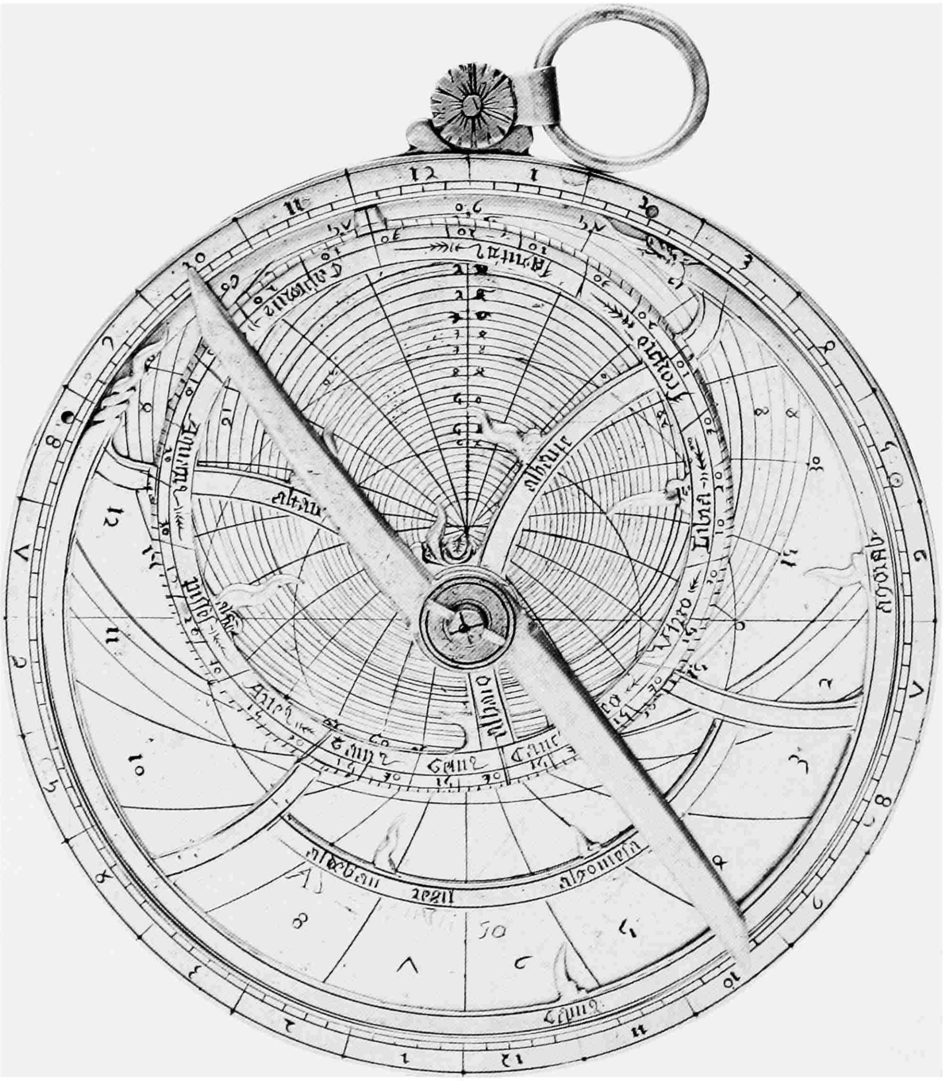


FIGURE 99.—Astrolabe No. 304. Front view.

six-petalled rosettes. The rim is divided by two scales of 12 hours (outer circle) and a scale of 12 minute intervals (inner circle). Stereographically projected horizon, altitudes (every 4°), azimuths (every 15°), and unequal hours for "LA 52" fill the front central area.

The outer margin of the back is divided into four altitude scales. A circular zodiac scale (subdivided into units of 15°) divides the margin just inside the altitude scales. An eccentric calendar scale has been engraved just inside the zodiac scale. The date of the vernal equinox is 11 March. Two shadow squares (incorporating finger units) divide the lower quadrants. The inscription is in Latin.

There are no separable plates. The rete design incorporates a Y-shaped structure inside the ecliptic and a double-linked equinoctial band between the ecliptic and the Tropic of Capricorn. There are 13 star pointers, only 11 of which are identified with Latin inscriptions. The two uninscribed pointers are the head and tail of a dragon. Except for a face with a long nose (inscribed "Vega"), all other pointers are flame-shaped. The ecliptic is divided partly into units of 15° (lower portion) and partly into units of 10° (upper portion).

The alidade is counterchanged about the center. It is uninscribed. Each of the two sighting plates has a single hole above the fiducial line. The pin is a cylinder with a head decorated with a five-petalled rosette. The wedge is just what its name implies. The index arm is complete and counterchanged about the center.

Remarks: The gothic, uncial letters "d," "q," "p," "n," "c" (or "e"), and "l" have been stippled onto the upper quadrants on the back of this astrolabe. No other known instruments have been marked in this way.

CCA No. 2005

(Figures 29, 100)

Date: Ca. A.D. 1580.

Signature: None.

Components: Body with throne, handle, ring, one plate, rete, alidade, rule with pin, and wedge

Diameter: 248 mm.

Material: Brass.

Characteristics: A circular depression with a movable cover has been incorporated into the front side of the throne. The throne itself is a triangular shape formed by scrollwork. The remainder of the suspensory apparatus consists of a pin with an eye (for holding the ring) attached to the throne with a circular washer and a square nut. The rim is divided into equal hours (two sets of twelve) and degrees (four arcs for measuring altitude). The front central area is blank. There is a cylindrical post near the rim at 270°.

The outer margin of the back face is engraved with a scale of degrees (again four arcs for measuring altitude). A de Roias projection consisting of 37 parallels of declination and 37 meridians fills all four quadrants. The positions of six bright stars (inscribed "CIGNVS, AQVILA, COR LEONIS, CADE CAPRICOR, CANIS MINOR, OCVLVS TAVRI") and the ecliptic are included in the projection. None of the meridian lines extend to the north and south points, but all stop at the engraved parallels for declination 66° north and south of the equator. There are no engraved details or original markings on the edge of the instrument.

The single preserved plate has a circular hole at 270°. It contains on the one side a conventional stereographic projection for latitude 45°, and on the other the scales usually found on the back of European astrolabes. The former includes altitudes (every 9°), azimuths (every 10°), houses (all 12 numbered with Roman numerals), and unequal hours. The latter consists of the following marginal scales: a scale of equal hours (in two groups of 12); a scale of 360 equal divisions; a set of four 90° scales which, because of their orientation, measure zenith distance; a second scale of 360 equal divisions; a set of twelve 30° scales; a zodiacal scale inscribed with symbols; and concentric calendar scales on which the names of all the months except "MARZO" are abbreviated. The vernal equinox corresponds to 12 March. There is a scale of unequal hours in the upper right quadrant of this second plate face. In the lower left quadrant is a scale for converting equal to unequal hours; it is inscribed in Latin. The

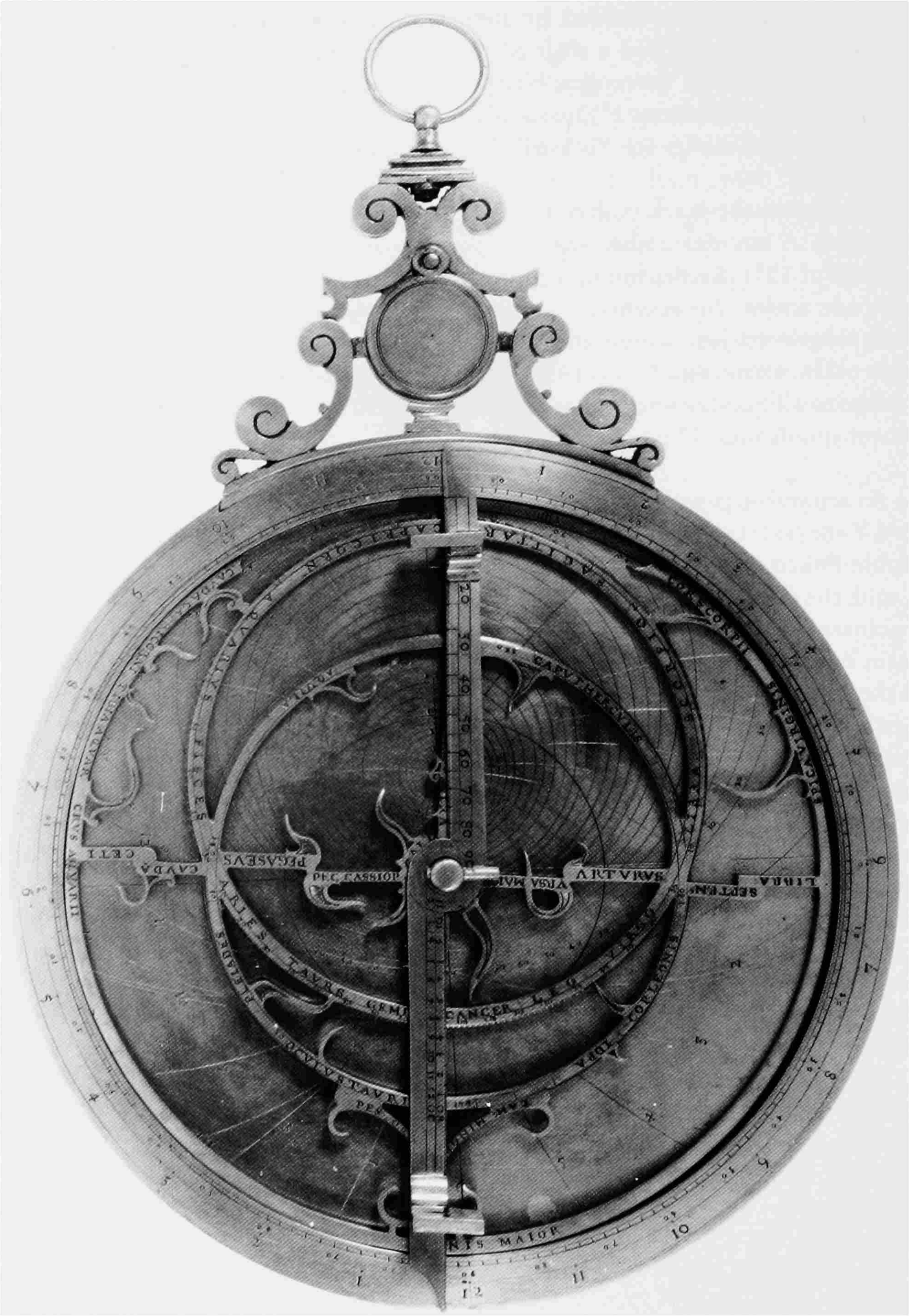


FIGURE 100.—Astrolabe No. 2005. Front view.

lower right quadrant contains a shadow square divided into fingers.

The east-west bar of the rete is counterchanged six times. A meridian bar extends between the upper portion of the complete equinoctial circle and the ecliptic. A pair of symmetric scrolls supports the lower portion of the equinoctial arc. There are 25 lambent star pointers engraved with

Latin names. The ecliptic circle is subdivided into units of 1° and units of 10°.

The alidade arm is counterchanged; it has a beveled fiducial edge and tapered outer ends. One arm is divided into 18 unequal parts, inscribed (from end to center); [blank], 20, 30, 40, 50, 60, 70, 80, 90. The other arm of the alidade is divided into 12 equal parts. Near the beveled edge these divisions are inscribed (center to end): 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, and 1. Along the arm these divisions are inscribed (center to end): 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and OC. The sighting plates are pierced with one hole above the fiducial edge. The pin is attached to a rule with outer ends shaped like brackets. This rule is divided by the orthogonal projections of azimuth circles. The wedge is a cylinder.

Remarks: The assignment of this astrolabe to the late sixteenth century is based largely on clues supplied by the rete. The rete pattern is quite similar to that adopted by Egnazio Danti about 1580. The longitude of Cor Leonis is appropriate for that time.

Analysis of the unequal divisions of the alidade arm indicates that these are the stereographic projection of points on a sphere between the pole and the equator of a circle of radius equal to the radius of the Tropic of Capricorn on the plate of this astrolabe.

CCA No. 2006

(FIGURES 16, 20, 28)

Date: See "Remarks."

Signature: See "Remarks."

Components: Body with throne, handle, ring, rete, alidade, pin, and wedge.

Diameter: 127.5 mm.

Material: Brass.

Characteristics: The throne of this astrolabe is shaped like a narrow rectangle connected to a disk. The stirrup-shaped handle has a revolving attachment for holding the ring. Plates decorated with an embossed braided rope molding have been applied to the front and back of the handle. The ring has a circular cross-section.

The wide rim is divided by three different scales. The outer one consists of two sets of 12 equal hours. Inside this is a scale consisting of four altitude arcs. Inside this is a zodiacal scale. The front central area contains stereographically projected horizon, altitudes (every 4°), azimuths (every 10°), and unequal hours for latitude 52°.

There are no marginal scales on the back of this astrolabe. Instead, all the scales and engraved lines likely to be found on a quadrant occupy the entire back area. The stereographically projected lines that have been folded into the quadrant include: tropics and equator, divided ecliptic, unequal hours, and horizons, identified as follows:

City	*Latitude*
IERUSALEM	[34]
CARTAGO	[38]
ROME	[42]
PARISIUS	[49]
OXONIA	[52]
BERWYK	[57]

The perimeter of the quadrant is divided by various scales. Along the arc are scales of degrees of right ascension (5° and 10° units) and degrees of longitude (5° and 10° units). The radial borders are divided by scales of terrestrial latitude (10° and 4° units) and celestial declination (10° and 4° units) and by sexagesimal scales of sines (in units of 10, 5, 1). A shadow square (divided into fingers) has been engraved tangent to the arc of the quadrant. A plumb bob hangs across the engraved quadrant from a rectangular hole at the upper corner of the quadrant square.

The star-pointer supporting rete structure forms a Y inside the ecliptic and a brace (⌒) between the ecliptic and the Tropic of Capricorn. All 25 star-pointers are identified with Latin inscriptions. Only three pointers are flame-shaped; one other pointer is a bird. The remaining pointers are shaped like heads of dogs. The ecliptic band is divided into units of two 2° as well as units of 10° and 30°. A calendar scale has been engraved on the Capricorn circle. When consulted in conjunction with the zodiac scale, it shows that the vernal equinox is 12 March. The back of the rete has been signed and inscribed as a sundial for latitude 53°15′. In addition, two Latin star names have been engraved on the back of dog-shaped pointers.

The alidade is counterchanged about the center. Its sighting plates are notched above the fiducial line. The pin is a cylinder with a flat head. The wedge is a rectangle.

Remarks: The number symbols and contractions used in inscriptions on the body and rete of this instrument suggest a fifteenth-century origin. The hand used to inscribe the sundial and to sign the back of the rete is obviously different from the hand of the other inscriptions. The natural conclusion is that the signature can be related only to the sundial and not to the astrolabe. Two knobs visible on the front of the rete may have been used to attach a gnomon to the dial face. The hour lines radiate from the back of one of these knobs. The engraved lines are appropriate for use with a gnomon inclined at an angle equal to latitude 53°15′. The inscribed name may be that of Thomas Wright, an English instrument maker who made orreries and surveyor's levels in Fleet Street, London, between 1715 and 1740.

CCA No. 2007

(FIGURES 27, 101)

Date: A.D. 1584 and 162? (see "Remarks").

Signatures: (1) PHILIPVS Danfrieus Siderographus Regius Generalis Lutetiae, (2) Franc. Galandius, and (3) À PARIS Chez Johan Moreau rue St. Jacques à la Croix blanche.

Components: Body (paper-covered wooden frame) with handle (brass) and ring (brass), four plates (paper), rete (paper), alidade (brass), index arm (brass), rivet screw (brass), and wing nut (brass).

Diameter: 207 mm.

Materials: Wood, heavy paper, and brass.

Characteristics: The truncated triangular throne is decorated on the front with a grotesque mask in a human likeness and on the back with a grotesque mask in an animal likeness. The handle is stirrup-shaped with a revolving attachment for holding the ring.

The rim is divided by the following scales: 24 equal hours identified as two sets of 12; 360 equal divisions; and a set of four altitude arcs. On the second scale, every other division is shaded. The front central area is blank.

The marginal scales on the back include: a set of four altitude scales; a scale of 720 equal divisions; a scale of 360 equal divisions; a set of twelve 30° scales; and a set of 12 pictures symbolizing the signs of the zodiac. A series of eccentric circular scales inside the marginal scales include a Gregorian calendar of epacts and a calendar of days and months. The 12 months are identified both with inscriptions and with allegorical pictures. The vernal equinox is 21 March. The two lower quadrants contain shadow squares divided sexagesimally. Inside the rectangle formed by these squares the following lines have been engraved:

> Ad inuenienda autem nouilunia Epactæ
> Iuxta singulos dies mensium hic scriptæ
> sunt Quare cuicunq diei adiacet an̄i labentis
> Epacta eo die fieri nouiluniũ scire conuenit

This can be translated, "The epacts are written next to the days of the month so that one can find the new moon. Thus, the epact for the current year adjacent to a given date indicates a day of new moon."

The maker's signature appears below the shadow squares. The upper quadrants contain wheels to be used to assist in converting from one calendar date to another. The wheel in the upper left quadrant is identified with the following inscription:

> Vsus harum duarũ
> Rotularum ab anno
> 1582 vsque in vltimum
> diem futuri proxime
> Seculi duraturus est

"These two wheels can be used from 1582 until the last day of the next century."

The wheel on the upper right quadrant is identified with the following inscription:

> [Dies domenica] p[ro]xime
> Sequinti Pascalis
> Indicem [que est
> lunia] decima quarta
> Primi mensis, sacrũ
> Pascha celebratur

FIGURE 101.—Astrolabe No. 2007. Front view.

"Easter is celebrated on the first Sunday following the Paschal Index, which is the full moon of the first month."

The following inscription appears in the left spandrels of the upper quadrants:

Hoc Dorsum kalendario
reformato precise
acomodatum
est

"This Back is precisely adjusted to the reformed calendar." Also in the upper quadrants is the address of Chez Moreau.

Each of the four plates has a tooth at 90°. One plate face is blank, but all the others contain stereographically projected horizon, twilight, altitudes (for every 2°), azimuths (every 5°), houses (all twelve), and unequal hours. The functional plates are identified with the following inscribed latitudes:

Plate	*Latitude*
1b	48
2a	39
2b	45
3a	42
3b	51
4a	54
4b	57

The rete pattern consists of a baroque design involving interwoven strapwork. The 28 flame-shaped star pointers are each engraved with Latin star names. The ecliptic is subdivided into units of 1° and units of 5°.

The alidade, inscribed "Franc. Galandius," is counterchanged about the center. There are no engraved scales. The sighting plates are pierced in the plane of the fiducial edge by a slit above a hole. The complete index arm is also counterchanged about the center. No scales divide it. A button-headed rivet screw and wing nut serve as "pin and wedge."

Remarks: The use of the various calendar scales is explained in the introduction to this catalog. The dates on this astrolabe may be interpreted as follows: the date 1584 associated with Philip Danfrie specifies the date when Danfrie engraved the plates from which paper astrolabes of the style illustrated by the example were printed; and the date 162? associated with the dealer Johan Moreau may be interpreted as the *terminus ad quem* for the "publication" of this particular instrument. Another astrolabe signed by Danfrie (and dated 1578) is preserved by the Service Hydrographique de la Marine in Paris (CCA No. 524).

CCA No. 2566

(FIGURES 102, 103)

Date: Ca. A.D. 1850.
Signature: None.
Components: Body, handle, ring, four plates, rete, alidade, pin, and wedge.
Diameter: 151 mm.
Material: Brass.
Characteristics: The throne is shaped like a high Moorish arch. It is decorated on front and back with engraved vines, which on the front follow the shape of the throne and on the back form a heart. The stirrup-shaped handle has a perforated crest. The soldered, circular ring is 19 mm in diameter. The rim contains a scale of 360°. The first division of this scale is labeled "5" and the last division is labeled "360" in *abdjad* numerals. Inside the front central area there is a gazetteer which lists 34 places along with the longitude, latitude, and azimuth of the Qibla for each. An inscription at the center of the gazetteer list reads:

ﻤﺖ قبلة درين بلاد همه غربى جنوبى است الا
مشق.

It can be translated: "The direction of these cities [from Mecca] is S.W. except for Damascus" (GS). There is a post projecting from a point near the rim at 270°.

On the back of the astrolabe, the outer margin contains two altitude scales in the upper quadrants. There are cotangent scales in the lower quadrants which are divided into feet (left) and fingers (right). The upper right quadrant contains stereographically projected declination arcs.

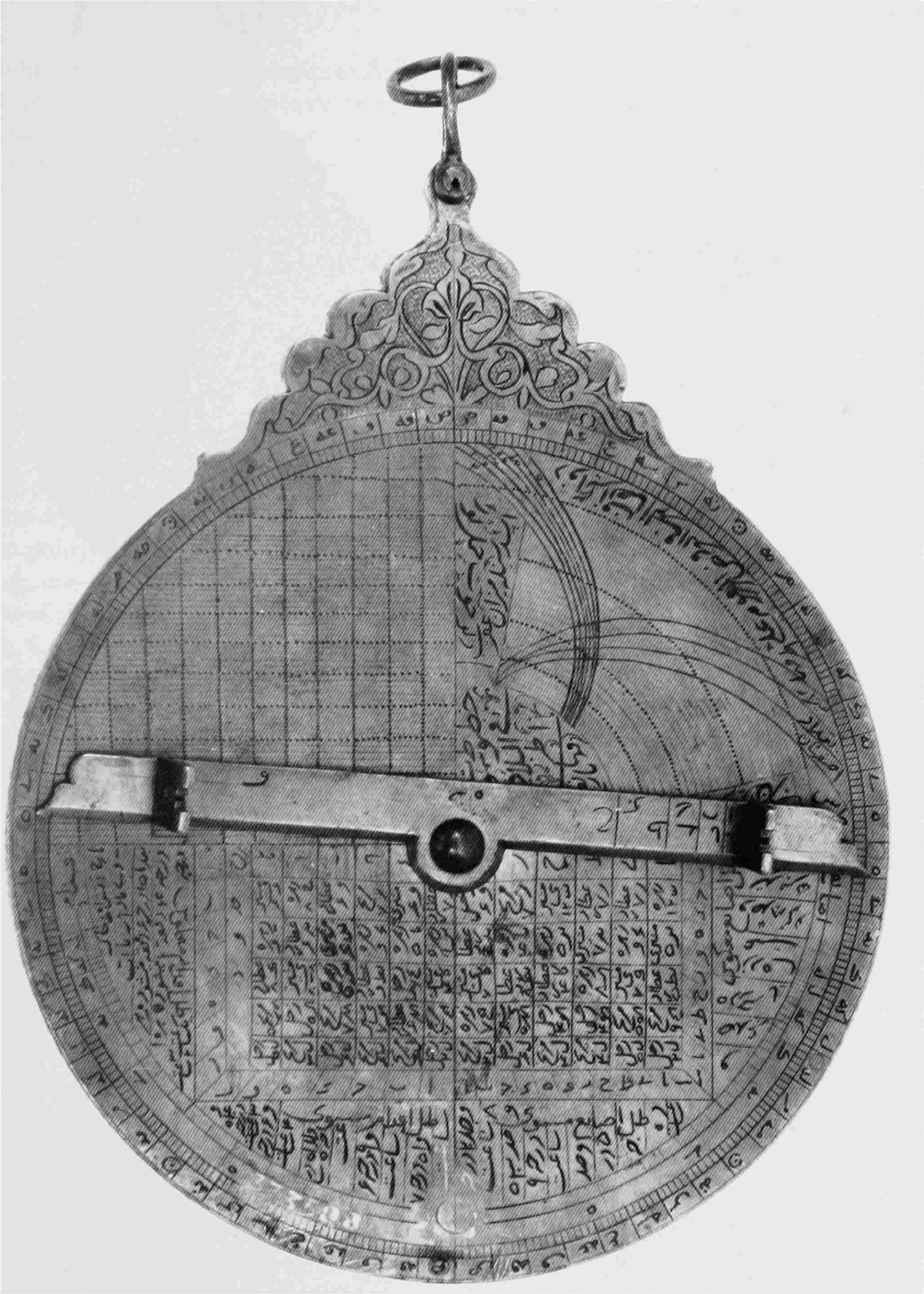
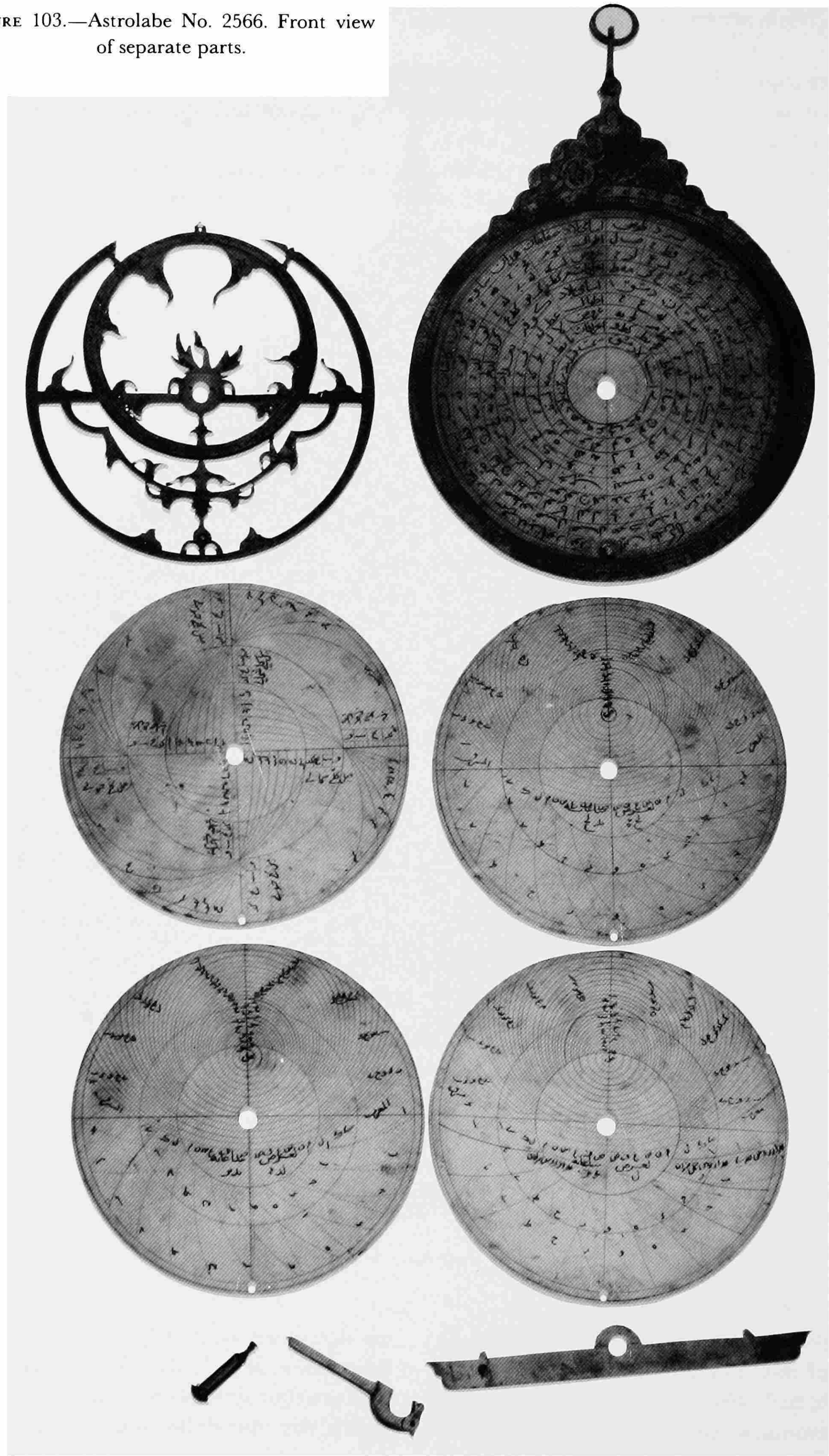


FIGURE 102.—Astrolabe No. 2566. Back view.

Graphed on these arcs are seven lines representing the altitude of the noon sun at latitudes 5°, 15°, 20°, 25°, 30°, 35°, 40° The inscription relating to this graph outside the outermost declination arc has been transcribed and translated in the description of CCA No. 59. Also graphed on these arcs are four lines representing the azimuth of the Qibla for the following cities: Ṭus (bottom),

FIGURE 103.—Astrolabe No. 2566. Front view of separate parts.



Iṣfahan, Baghdad, Shiraz. For a transcription and translation of the inscription relating to this graph inside the innermost declination arc, see the description of CCA No. 49. Sines and cosines divide the upper left quadrant. Shadow squares divided into feet (left) and fingers (right) occupy the lower quadrants. The area circumscribed by these squares is divided into 6 rows and 13 columns. The rows in the first column contain the title of the scale inscribed in the remaining rows and columns. The scale proceeds from top to bottom and from right to left, and gives the names of the planetary governors of terms, the number of degrees in each term division, and the position of each term division in its zodiacal sign. According to Saliba, the poorly written inscription outside the shadow squares associates angular measures with measures of time, such as 1° with 4 minutes and 90° with 6 hours. He notes, however, that many of the associations are erroneous: 54° with 3 hours, 51° with 5 hours. The entire outer edge is inscribed.

The astrolabe is fitted with four plates. There is a small hole in each near the edge at 270°. On one plate face there are 28 stereographically projected quarter horizons, one for every 2° of latitude between 12° and 66°. Each of the other plate faces contains a network of stereographically projected coordinates for a single latitude. On two of these faces (3b and 4b), the stereographically projected coordinates include altitudes (every 2°), azimuths (every 5° or every 10°), and unequal hours. Lines representing the equal Italian hours have been projected onto the other faces. Identifying inscription on the plates reads:

Face	*Latitude*		*Length of daylight*	
1b	*ᶜarḍ*	42 00	*sāᶜātuhu*	15 4
2a	*ᶜarḍ*	34 00	*sāᶜātuhu*	14 17
2b	*ᶜarḍ*	32	*sāᶜātuhu*	14 7
3a	*ᶜarḍ*	30	*sāᶜātuhu*	13 17
3b	*ᶜarḍ*	28 00	*sāᶜātuhu*	13 39
4a	*ᶜarḍ*	38 5	*sāᶜātuhu*	14 38
4b	*ᶜarḍ*	36 00	*sāᶜātuhu*	14 29

The rete design includes a complete equinoctial colure without counterchanges. There is a portion of a celestial equator outside the ecliptic. A foliated central support of the equator contributes to the generally symmetric pattern. An inscription along the Capricorn band appears to associate signs of the zodiac with masculine or feminine natures, with "changing," "stable," or "mutable" characters, with the elements of fire, earth, wind, or water, with a planet, and with numerals. It reads:

حمل مذکر منقلب اتش خانه مریخ ۲۰۱ ۰ ثور مؤنث
ثابت ترابی خانه زهره ٤١ ۰ جوزاء دوحد باد
مذکر خانه عطارد ٤٢ ۰ سرطان منقلب مؤنث خانه
قمر ابی ۲۰۲ ۰ اسد خانه افتاب ثابت اتش مذکر
۲۰۲ ۰ سنبله خانه عطارد دوحد ترابی مؤنث ٤٢ ۰
میزان خانه زهره مذکر منقلب باد ٤٢ ۰ عقرب
خانه مریخ مؤنث ثابت آب ۲۰۲ ۰ قوس خانه مشتری
دوحد اتش مذکر ٤٠٢ ۰ جدی خانه زحل منقلب خاکی
مؤنث ۲ ۰ دلو خانه زحل ثابت باد مذکر ٤٠٠١ ۰
حوت خانه مشتری دوحد آبی مؤنث ۲۰۱ ۰

A tentative translation reads as follows:

Aries, Male, Changing, Fire, House of Mars, 201;
Taurus, Female, Stable, Earth, House of Venus, 41;
Gemini, Mutable, Wind, Male, House of Mercury, 42;
Cancer, Changing, Female, House of the Moon, Water, 202;
Leo, House of the Sun, Stable, Fire, Male, 202;
Virgo, House of Mercury, Mutable?, Earth, Female, 42;
Libra, House of Venus, Male, Changing, Fire, 42;
Scorpio, House of Mars, Female, Stable, Water, 202;
Sagittarius, House of Jupiter, Mutable?, Fiery, Male, 402;
Capricorn, House of Saturn, Changing, Earth, Female, 2;
Aquarius, House of Saturn, Stable, Fire, Male, 4001;
Pisces, House of Jupiter, Mutable?, Water, Female, 201 (GS).

There are 23 named star pointers. The ecliptic band is subdivided into units of 6°. Tropics, equator, and ecliptic divisions have been engraved on the back of the rete. The alidade is not counterchanged. One arm has been divided into the five unequal hours; the other arm contains 11 equal divisions. Each sighting plate is pierced by

two holes and notched at its upper edge. The pin is a bolt with a tapering end. The wedge is shaped like the heads of a horse, upon which eyes and mane have been engraved.

The inscription is Arabic Naskhi.

Remarks: The inscription on this astrolabe suggests that at least two different scribes were responsible. One hand is apparent in the scales on the back of the astrolabe; another in the tables in the lower quadrants and around the edge. There is further evidence of combined efforts on the plates, where the azimuths are numbered in a hand different from that used elsewhere on the plates. The maker(s) have employed some dotted lines in the upper quadrant on the back and on the plates. The upper left quadrant is only crudely divided. The rete shows evidence of repair. Its pattern is identical to that of No. 64. Neither holes nor notch of sighting plates lie above the alidade's fiducial line.

CCA No. 2567

(FIGURES 104, 105)

Date: A.H. 1067 [1656].

Signature: ᶜamal [?] Khalil.

Components: Rim with throne attached to backplate with throne, handle, ring, two plates, rete, alidade, pin, ringlet, and wedge

Diameter: 132 mm.

Material: Brass.

Characteristics: The throne of this astrolabe is quite high and pierced to form intertwined vines. The stirrup-shaped handle has a double lunate cross-section. The rim contains a scale of 360° divided by units of 1° (uninscribed) and 5° (inscribed). The front central area is blank except for engraved projections of the solstitial and equinoctial colures.

The upper half of the margin at the back of the astrolabe contains two altitude arcs. The lower half of this margin is blank. There are no scales in the upper half of the quadrant area. The lower half of the quadrant area contains two adjacent shadow squares.

The two plates are each notched at 270°. All faces contain stereographically projected horizon (inscribed), altitudes (every 6°), and unequal hours. The projections are identified:

Plate	*Latitude*
1a	ᶜ*arḍ* 20
1b	ᶜ*arḍ* 24
2a	ᶜ*arḍ* 40
2b	ᶜ*arḍ* 35

The simple rete pattern includes the equinoctial colure and the lower arc of the equator circle. The ecliptic is subdivided into 60 units of 6° The 16 star pointers are dagger-shaped. The signature and date and parts of the stereographically projected equator and Tropic of Cancer are inscribed on the back of the rete.

There are no counterchanges in the alidade. The beveled edge of one arm is divided into 60 equal parts; every fifth division line continues onto the top of the arm. The units of five are numbered. Five unequal divisions on the other arm are not identified. Each sighting plate is pierced with one large hole. The pin is a bolt with a rosette head. The ringlet is octagon-shaped. The wedge is a high trapezoid.

The alphabet of the inscription is Arabic Naskhi.

Remarks: All of the engraving on this instrument is quite worn. The plates are particularly thin and crudely inscribed. Concerning the word ᶜ*amal* in the signature, Mayer[107] has said, "With the exception of a Sultan, not a single man who signed his astrolabe in this way is known from literature."

CCA No. 2568

(FIGURES 106, 107)

Date: A.H. 1103 [1691].

Signature: ṣanaᶜahu al-Ḥasan ben Aḥmad al-Baṭṭuṭi.

Components: Rim with throne, backplate with throne, handle, rin, end of cord, three plates, rete, alidade, pin, and wedge.

Diameter: 131.5 mm.

Material: Brass.

Characteristics: The throne is high, but un-

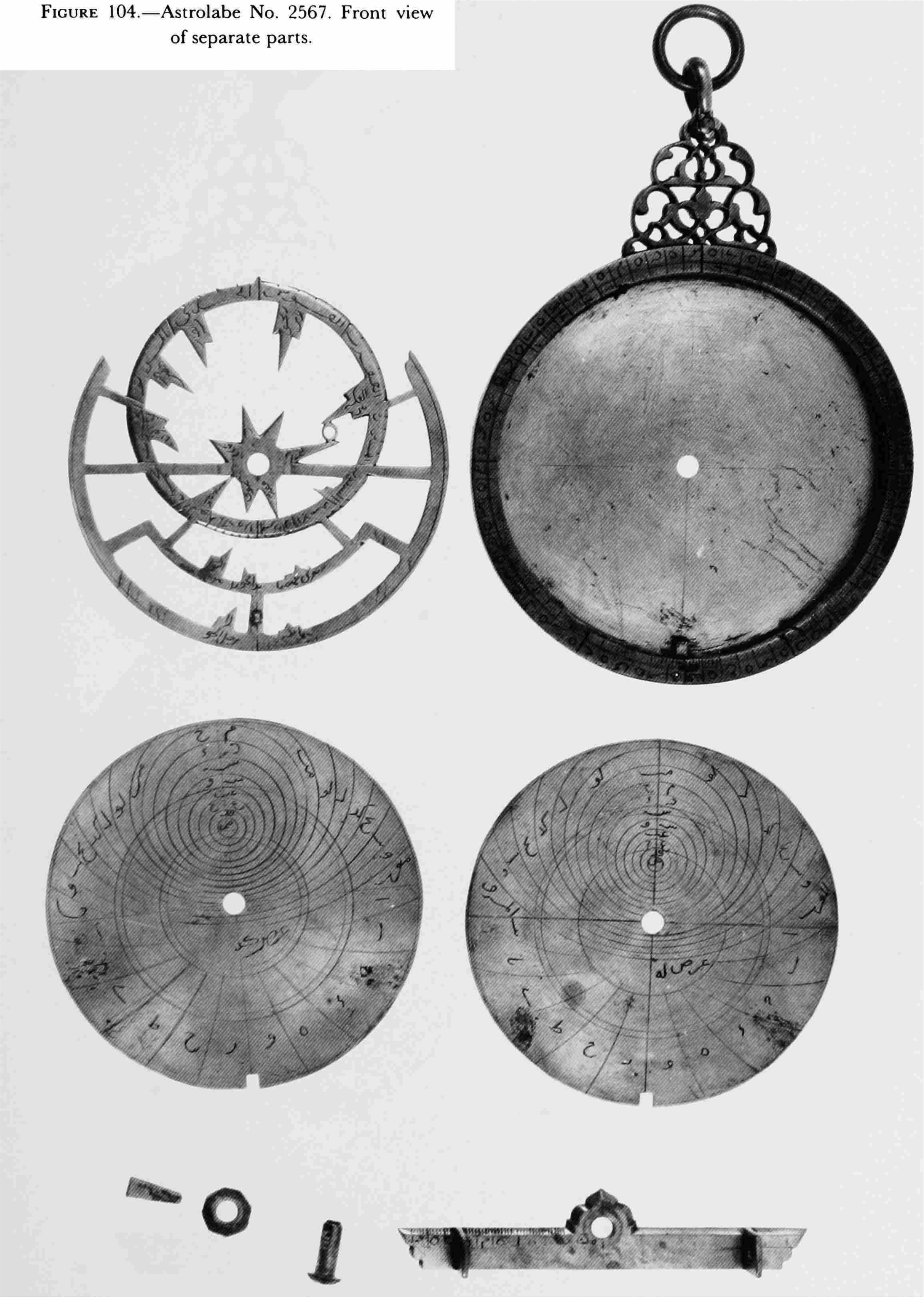


FIGURE 104.—Astrolabe No. 2567. Front view of separate parts.

FIGURE 105.—Astrolabe No. 2567. Back view of separate parts.

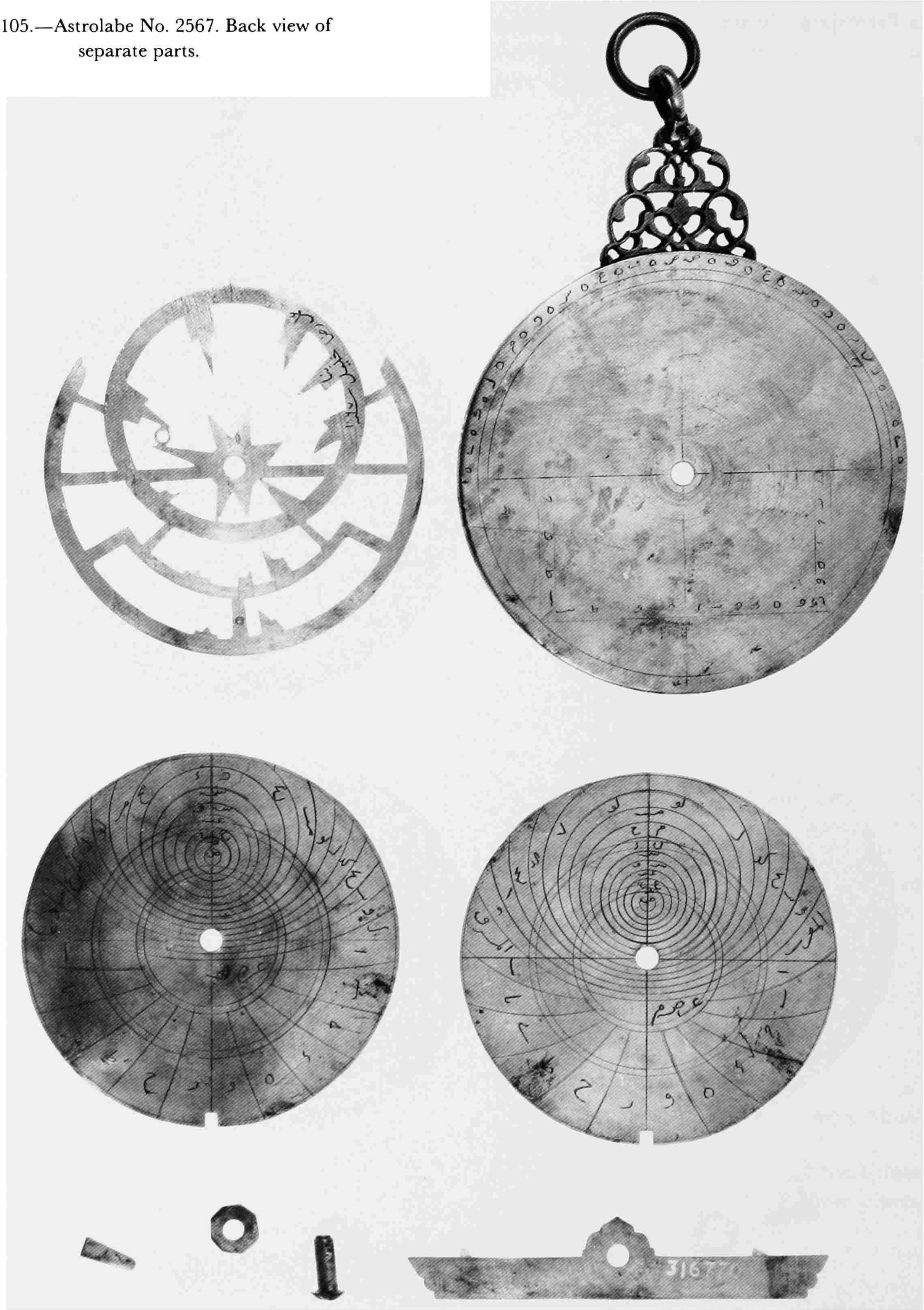
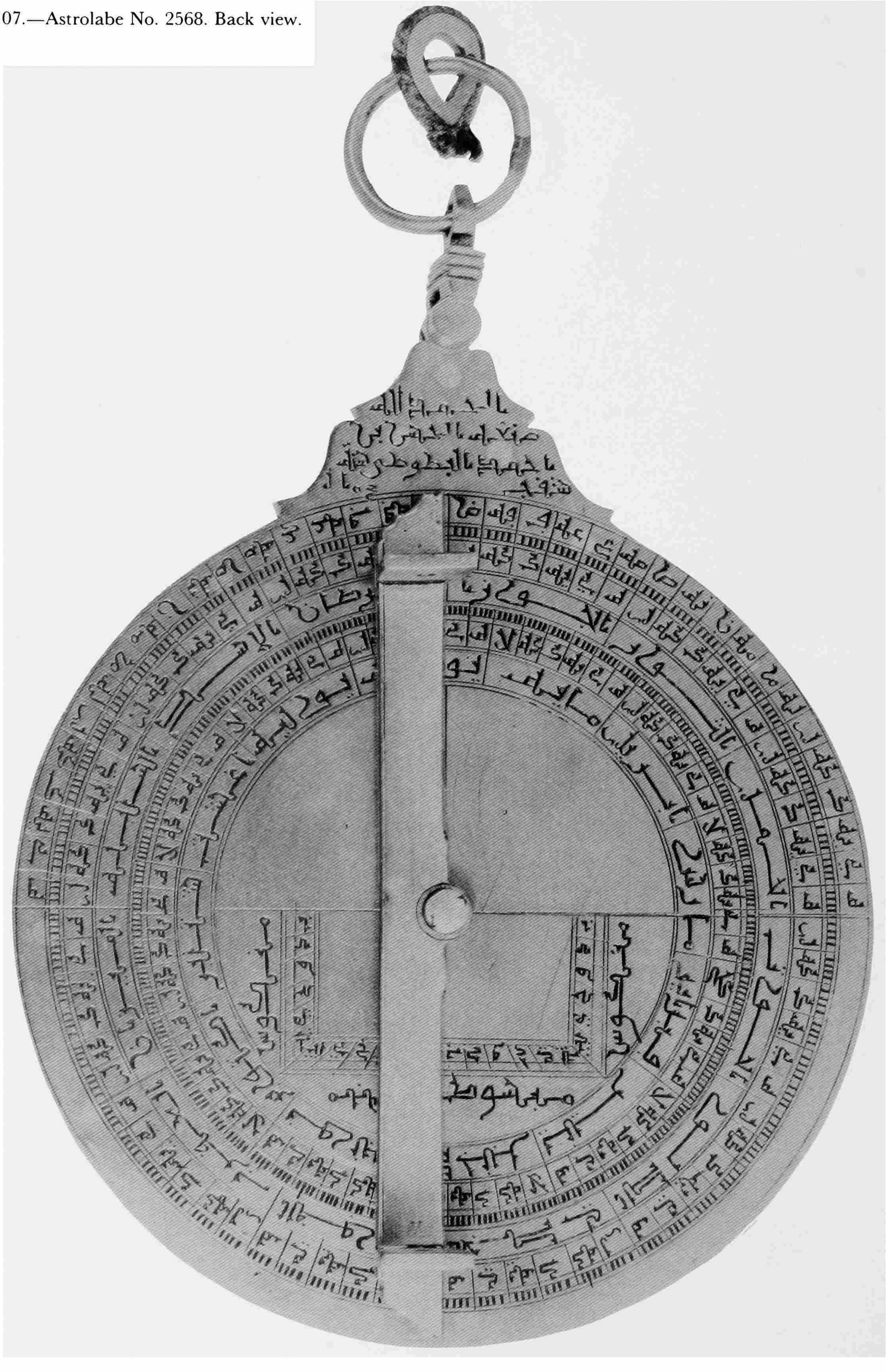


FIGURE 106.—Astrolabe No. 2568. Front view.

FIGURE 107.—Astrolabe No. 2568. Back view.



pierced and of simple design. Its edges have the shape of inverted brackets. In addition to a signature and date, the following phrase has been inscribed on the back of the throne: *al-Ḥamd li-Allah* (Thanks to God). The rim has been divided into a scale of 360°. The first division of the rim scale is inscribed with the Kufic number "5"; the last division has been inscribed "60." The latter indicates that the script is of western origin. The front central area is completely blank.

The upper half of the back margin is divided by two altitude scales. The lower half of this outer margin is blank. Just inside the margin there has been engraved a circular zodiacal scale and a concentric calendar scale. The date of the vernal equinox indicated by these scales is 9 March. The two upper quadrants are blank. Two shadow squares, divided into fingers, have been inscribed in the lower quadrants.

Each of the three plates has a tooth at 90°. All have been inscribed with stereographically projected altitudes (every 6°), azimuths (every 10°), unequal hours, and prayers. On each face, notched lines designate three altitude lines (for 18°, 30°, and 60°), the prime vertical, and the prayers. The projections are identified with the following inscription:

Plate	*Inscription*	
1a	*ᶜarḍ Mecca Sharrafaha Allah*	21
1b	*ᶜarḍ Ṭarābalus wa al-Jazāʾir*	
2a	*ᶜarḍ Maṣ* [?]	30
2b	*li-kull balad ᶜarḍuhu*	36
3a	*ᶜarḍ Marikāsh*	31 30
3b	*ᶜarḍ Fās*	33 40

The rete pattern incorporates an equinoctial colure (counterchanged four times) and an arc of the celestial equator. A small circle provides central support to this arc. There are 23 inscribed star pointers. The pointers are sickle-shaped with pierced balls on trefoils as bases. In addition, there is a pointer (uninscribed) along the inner edge of the ecliptic band near the boundary between Gemini and Cancer. The ecliptic band is subdivided into uninscribed units of 6°.

The alidade is neither inscribed nor counterchanged. Each of its sighting plates is pierced by a single hole. The pin is a bolt with a flat head. The wedge is a flat wire bent into the shape of a T.

The alphabet employed by the maker of this astrolabe is Arabic Kufic maghribi.

Remarks: The date on the back of the throne is written in both Kufic *abdjad* and Hindu-Arabic characters. Other astrolabes signed by al-Ḥasan include one dated A.H. 1097 [1685] in a private collection (CCA No. 2707) and one dated A.H. 1106 [1694] in the Museum of Islamic Art in Cairo (CCA No. 3804).

CCA No. 2569

(FIGURES 108, 109, 110, 111)

Date: Ca. 1650.

Signature: None.

Components: Backplate with throne, rim, front throne, handle, ring, brass chain, five plates, two retes, alidade, pin, and wedge.

Diameter: 153 mm.

Materials: Brass.

Characteristics: The throne is a high pierced Moorish arch decorated with embossed vines and flowers. The stirrup-shaped handle has a diamond cross-section. The ring also has a diamond cross-section. The brass chain is in excellent condition.

The rim of this instrument is divided into four 90° arcs. These arcs are further subdivided into units of 6°, 2°, and 1°. Division lines are dotted. The gazetteer engraved in the front central area lists 97 place names along with their terrestrial latitude and longitude. A tooth projects into the front central area at 270°.

The upper half of the margin on the back of this instrument contains two altitude scales, divided by dotted lines into units of 6°, 2°, and 1°. Dotted lines divide the lower left margin into the fingers of a cotangent scale; the feet of a cotangent scale divide the lower right margin. Equally spaced declination arcs (some dotted) divide the upper right quadrant. Dotted lines representing the altitude of the noon sun at latitudes 27° and 32° have been graphed onto the declination arcs. These are inscribed: *khaṭṭ niṣf al-nahār li-ᶜarḍ 27*

FIGURE 108.—Astrolabe No. 2569. Gazetteer.

(upper) and *khaṭṭ niṣf al-nahār li-ʿarḍ 32* (lower). Sixty equally spaced sine lines (some dotted) divide the upper right quadrant. The shadow square in the lower left quadrant is divided into 60 equal units; the shadow square in the lower right quadrant is divided into feet. The lower quadrants of this astrolabe also contain nine astronomical or astrological tables. Three of these are rectangular and divide the area inside the shadow square. The upper left one is a table of triplicities, labeled,

جدول ارباب مثلثات ليلى ونهارى

or, "Table of rulers of triplicities by night and day" (GS). The lower one is a table showing multiples of the difference (in degrees and minutes) between the approximately correct length of the tropical year and 365 days, labeled,

FIGURE 109.—Astrolabe No. 2569. Back view.

جدول فضل الدور

This translates as, "Table of excess of revolution" (GS). The upper right rectangular table gives the length of longest daylight in hours and the corresponding latitude for upper and lower limits of the seven "climates" or bands of geographic latitude, titled:

جدول عروض • • • ساعات نصف النهار

which translates as, "Table of extent of [?] hours at midday" (GS). The six circular tables include lunar mansions, zodiacal signs, planetary governors of terms, terms, planetary governors of decans, and decans.

Each of the five plates included in this instru-

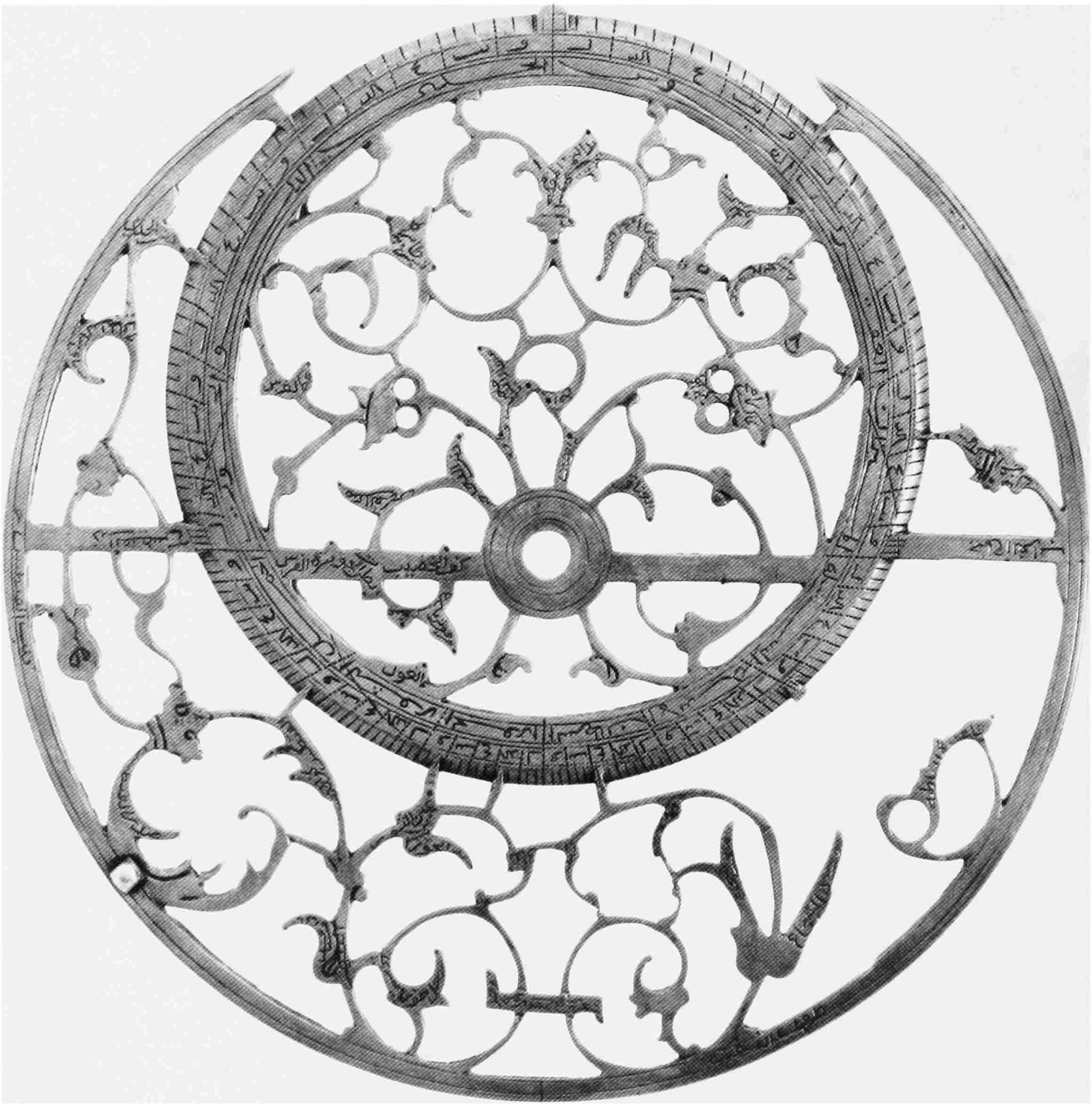


FIGURE 110.—Astrolabe No. 2569. Full ᶜ*ankabūt* (2569A).

ment has a notch at 270°. One plate face contains 67 stereographically projected quarter-horizons—one for each degree of latitude between 4° and 65°, four for latitude 66°30′, and one for latitude 70°. There are also four obliquity scales at the ends of the projected colures. The greatest obliquity is 23°30′. All remaining plate faces contain stereographically projected horizon, altitudes (every 2°), and azimuths (every 6°). Eight of these also contain stereographically projected unequal hour lines and hour lines corresponding to the equal Italian hours. Some of the projected lines are dotted. The plates are identified with the following inscriptions:

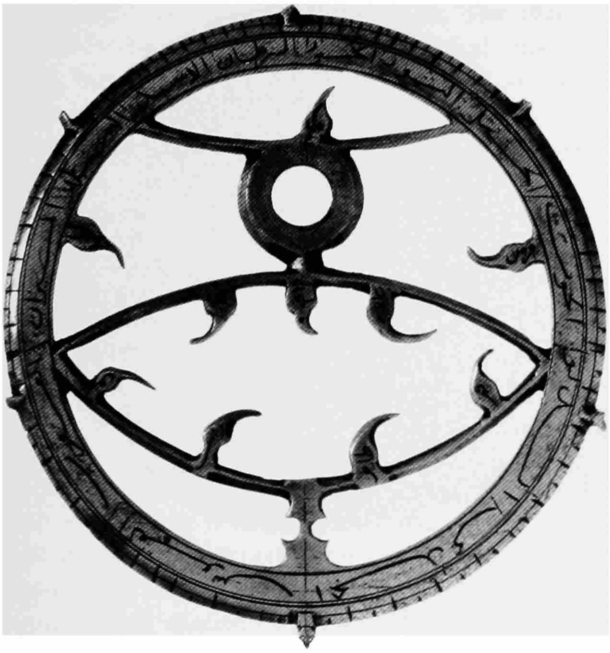


FIGURE 111.—Astrolabe No. 2569. Small ᶜ*ankabūt* (2569B).

Plate	*Latitude*		*Length of daylight*	
1a	*ṣafīḥa ᵓāfāqī*			
1b	*ṣafīḥa mīzān al-ᶜankabūt*			
2a	*li-ᶜarḍ*	25	*sāᶜātuhu*	13 25
2b	*li-ᶜarḍ*	27	*sāᶜātuhu*	13 43
3a	*li-ᶜarḍ*	29	*sāᶜātuhu*	13 52
3b	*li-ᶜarḍ*	32	*sāᶜātuhu*	14 08
4a	*li-ᶜarḍ*	30	*sāᶜātuhu*	13 53
4b	*li-ᶜarḍ*	38	*sāᶜātuhu*	14 42
5a	*li-ᶜarḍ*	36	*sāᶜātuhu*	14 32
5b	*li-ᶜarḍ*	40	*sāᶜātuhu*	14 52

This astrolabe is equipped with two retes. The design of the larger of the two is quite delicate and non-symmetric. It incorporates a counterchanged east-west bar, Tropic of Capricorn, and ecliptic. There are 43 inscribed star pointers, shaped like leaves. A dot on each pointer marks the position of the star. The ecliptic circle is subdivided into units of 6° and 2°. There are no markings on the back of this rete. The second rete is smaller and of simpler design, incorporating the arcs of three circles. The 10 leaf-shaped star pointers, all inside the ecliptic circle, are inscribed with the names of stars, most of which duplicate stars on the larger rete.

The alidade is not counterchanged. It is inscribed with three different scales: a stereographically projected declination scale on one arm and a scale of 60 equal divisions and a sundial on the other arm. Each sighting plate is pierced by three holes, with the uppermost largest and the other two of equal size. The pin is a bolt with a flattened hemispherical head and a knob tip. The wedge is a small trapezoid.

Remarks: This anonymous instrument exhibits many of the characteristics of astrolabes known to have been made in Lahore: dotted division lines, equally spaced declination arcs, graphed prayer lines, delicate rete. The rectangular "table of differences" on the back of this astrolabe is similar to tables included on astrolabes with the following CCA numbers: No. 78 (made by Muḥammad Muqim ben ᶜIsa in Lahore); No. 74 (made in India); and No. 94 (inscribed in Sanskrit). The rim scale is divided so that the arcs in the first and third quadrants measure zenith distance and the arcs in the second and fourth quadrants measure altitude. All five plates appear to have been engraved by the same astrolabist who was responsible for the inscription on the body. On the alidade, both the declination scales and the sundial are incorrectly lettered and the declination scale (at least) appears to have been re-engraved by someone other than the original maker. The errors could have been made by the person who made the obvious repairs on the alidade sighting plates. In fact, the present engraved area appears to have been laminated onto another alidade.

CCA No. 2570

(FIGURE 112)

Diameter: 94 mm.
Material: See "Remarks."
Remarks: This instrument can easily be distinguished from functional astrolabes. There is no holder for the four plates and there are no holes

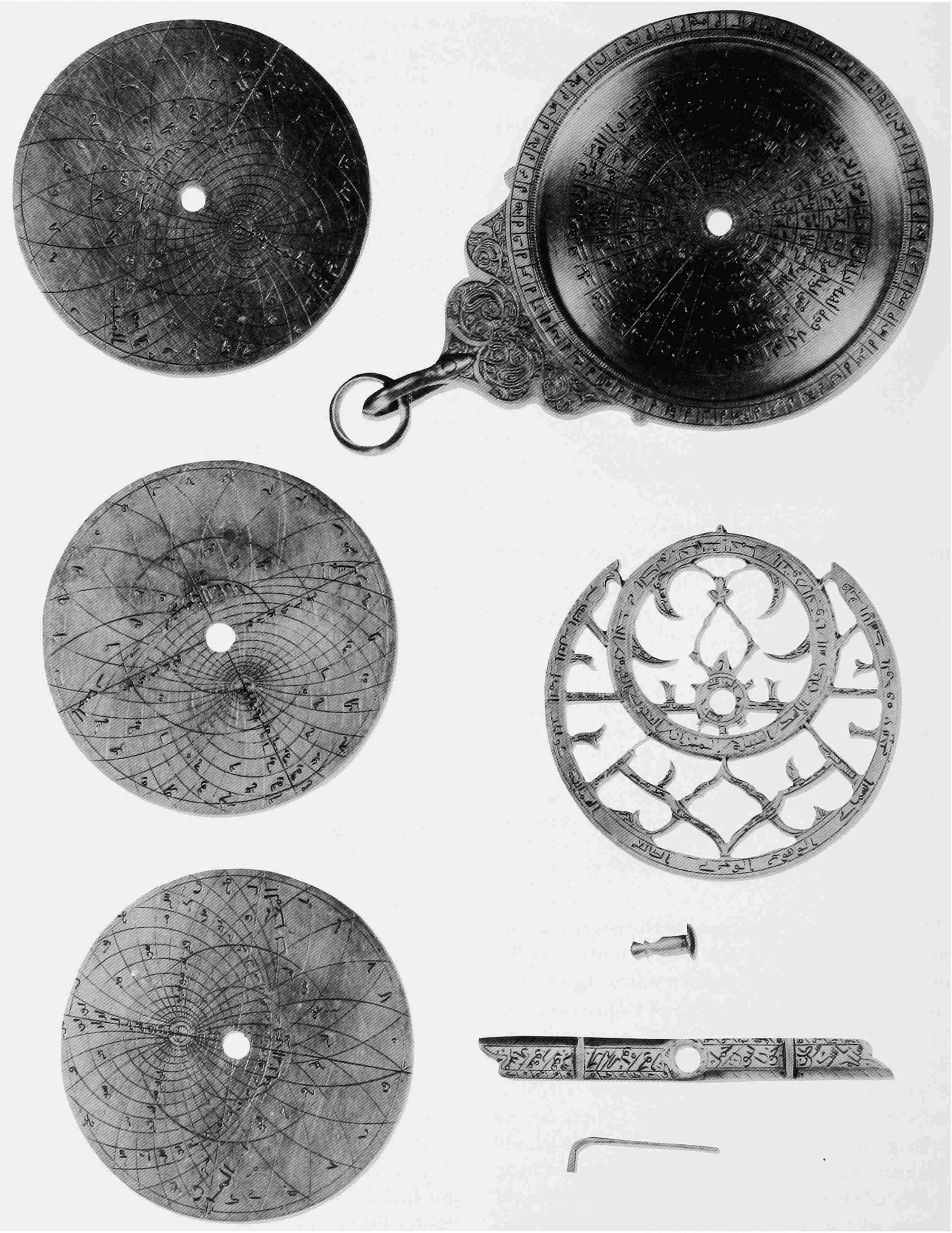


FIGURE 112.—Astrolabe No. 2570. Front view of separate parts.

in the sighting plates of the alidade. The rim of the body has been accurately divided into 72 units, but the numbering of these divisions proceeds in nonsensical order. The front central area has been neatly divided by concentric bands and radial lines, as if to contain a gazetteer, but again the inscribed numbers are meaningless. Of all of the scales engraved on the back of the astrolabe, only the altitude scales in the upper margin and a circular scale of zodiacal signs have any recognizable validity. All lines on the plates are neatly engraved and arranged as if stereographically projected. Identifying numbers, however, are inscribed virtually at random and the inscriptions purporting to give latitudes have no relation to reality. The rete is neatly patterned and includes a bird figure above center and a counterchanged equinoctial colure. The inscription of the ecliptic band, which should begin at 180° and proceed counterclockwise actually begins at 90° and proceeds clockwise. Most of the inscriptions on the rete are not familiar star names, and of the four recognizable names, two are obviously misplaced. The beveled edges on the alidade do not follow the fidicual line. Clearly legible names of zodiacal signs have been engraved on both arms but the numbers have no meaning. There is much internal evidence that the maker of this instrument was familiar with the language found on an astrolabe but that he knew nothing of the astronomy embodied in such an object. Neither the identity of the maker nor the provenance of this example of his work is known.

The script employed throughout is Arabic Kufic. The instrument is made of a silver-colored metal.

CCA No. 2571

(FIGURES 113, 114)

Date: A.H. 910 [1504].

Signature: ʿAli ben Muḥammad ben Abdallah ben Faraj.

Components: Rim with throne attached to backplate with throne, handle, three plates, rete, alidade, pin, and wedge.

Diameter: 178 mm.

Material: Brass.

Characteristics: The throne is low and shaped like a bracket. It is undecorated and uninscribed. The handle is shaped like a stirrup. The ring is pear-shaped with a groove around the outer edge. A scale of 360°, subdivided into units at 6°, has been inscribed on the rim. The first unit is designated "6;" the last unit, "60." There is a notch in the rim at 90°. A crude stereographic projection of colures, tropics, equator, altitudes, and horizon for approximately 30° has been engraved on the front central area.

On the back of the astrolabe, the upper margin is divided by altitude scales. Inside the margin, there are six complete concentric circular scales consisting of 1° and 5° subdivisions of the zodiacal signs, the zodiacal signs, one and five, six, or eight day divisions of the calendar year, and the Christian months. The date 13.5 March is opposite Aries 0°. The signature and date are inscribed in the upper quadrants. There are shadow squares in the lower quadrants. These are divided into fingers on the left and feet on the right.

There are three plates, each with a tooth at 90°. On one plate face (1a) there have been engraved stereographically projected straight lines, declination circles (19), horizons (15), and altitudes (15°N and 4°S of the horizon at latitude 0°). The face is identified as *li-jāmiʿ al-ʿurūḍ*. The other five plate faces contain stereographically projected coordinates for a single latitude. These coordinates include altitudes (every 3°), azimuths (every 10°), unequal hours, and lines representing times of prayer. The prayer lines are identified *fajr* (below the left horizon), *al-ʿaṣr* (within the tenth unequal hour), *aẓ-ẓuhr* (within the eighth unequal hour), *shafaq* (below the right horizon), *az-zawāl* (mid-heaven). On each plate face, an inscription identifies the latitude of the stereographic projection:

Plate	*Latitude*	
1b	*li-ʿarḍ*	31 30
2a	*li-ʿarḍ*	30
2b	*li-ʿarḍ*	33 40
3a	*li-ʿarḍ*	34 30
3b	*li-ʿarḍ*	36 30

The rete is a relatively simple design. It in-

FIGURE 113.—Astrolabe No. 2571. Front view.

cludes a counterchanged equinoctial colure and the lower portion of a stereographically projected celestial equator. This equator arc is supported by a central circle. There are 30 inscribed star pointers. Each of these extends from a base decorated with stud. The ecliptic is subdivided into units of 3° The tropics and equator circles have been engraved on the back of the rete. The plain alidade is not counterchanged. Each sighting plate is pierced with a single wide hole. The pin is a bolt with a flattened head. The wedge is an animal shape with engraved eyes, nose, and mouth.

The alphabet employed by this maker is Arabic Kufic maghribi.

Remarks: An astrolabist with the name ʿAli

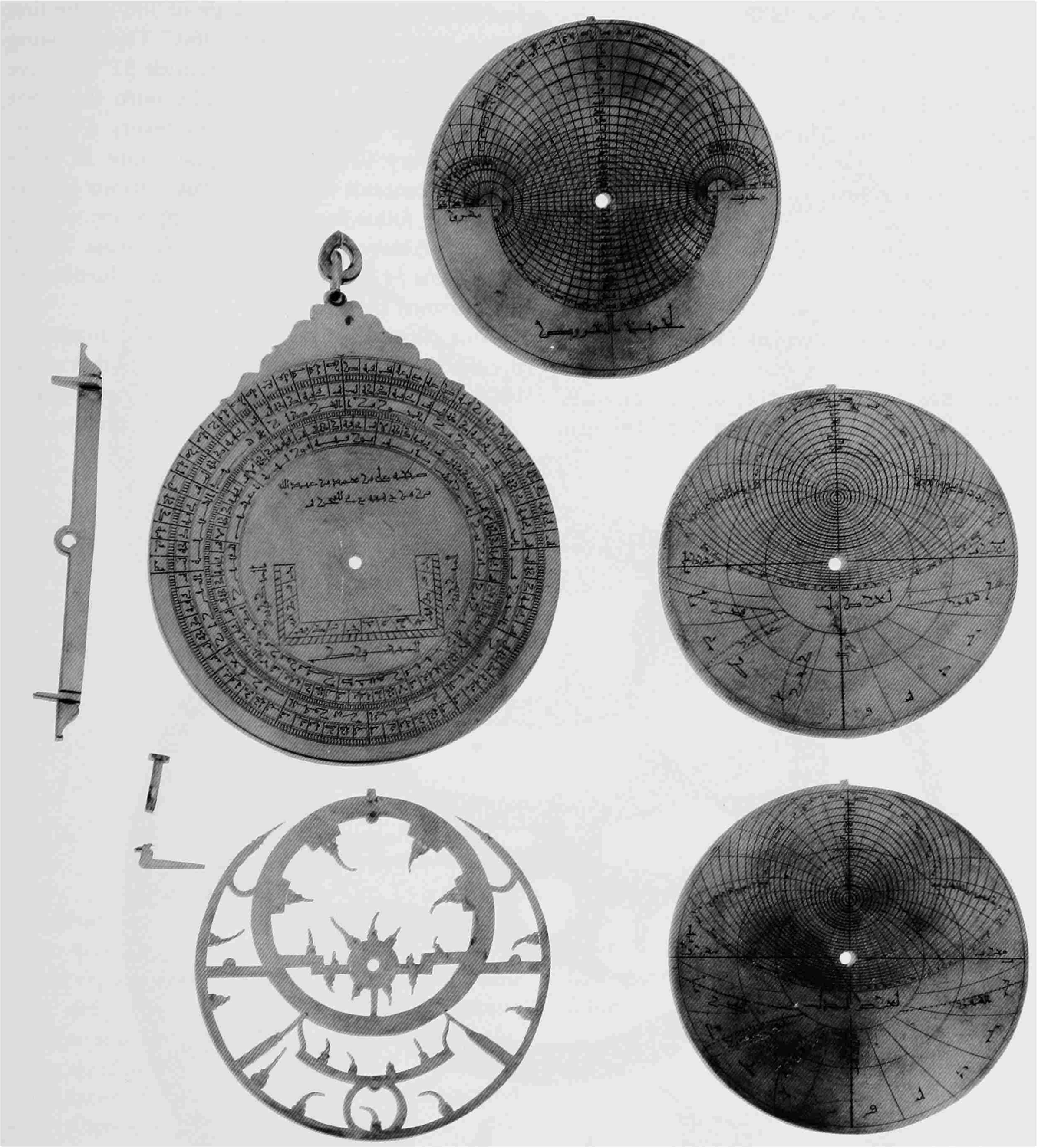


FIGURE 114.—Astrolabe No. 2571. Back view of separate parts.

ben Muḥammad ben [?] ben Faraj is listed in Mayer's *Islamic Astrolabists.*[108] An uncertainly read date of A.H. 1010 [1601] is assigned to the one example of the work of ᶜAli described by Mayer. Except for the use of a Kufic mashriqi numeral to designate 300, the instrument described in this catalog entry appears to be inscribed with Kufic maghribi characters. The rete shows signs of repair. Alidade, pin, and wedge are apparently replacements.

CCA No. 2572

(FIGURES 115, 116, 117)

Date: A.H. 483 [1090].

Signature: ṣanaᶜahu Muḥammad ben as-Sahli.

Components: Rim with throne attached to backplate with throne, handle, ring, five plates, rete, and pin.

Diameter: 107 mm.

Material: Brass.

Characteristics: The low Moorish throne is pierced by four holes, two on each side of the handle hole. The handle is shaped like a flattened stirrup decorated with pierced trefoils at its sides. The ringlet has a diamond cross-section. The rim has been inscribed with a scale of 360° The first unit is marked "5;" the last, "360." The following coordinates, appropriate for latitude 37°30′, have been projected stereographically onto the front central area: horizon, altitudes (every 6°), azimuths (every 10°), and unequal hours. In addition to numerals identifying the various projections, the following inscription appears: (below horizon) *Ishbiliyah wa Malagha wa Gharnaṭa ᶜarḍ 37 30 sāᶜātuhu 14 19*; (along the solstitial colure below the horizon) *khaṭṭ az-zawāl.*

Four altitude scales (one in each quadrant) divide the outer margin on the back of this astrolabe. The inner margin is divided by a zodiacal scale. An eccentric calendar scale divides the

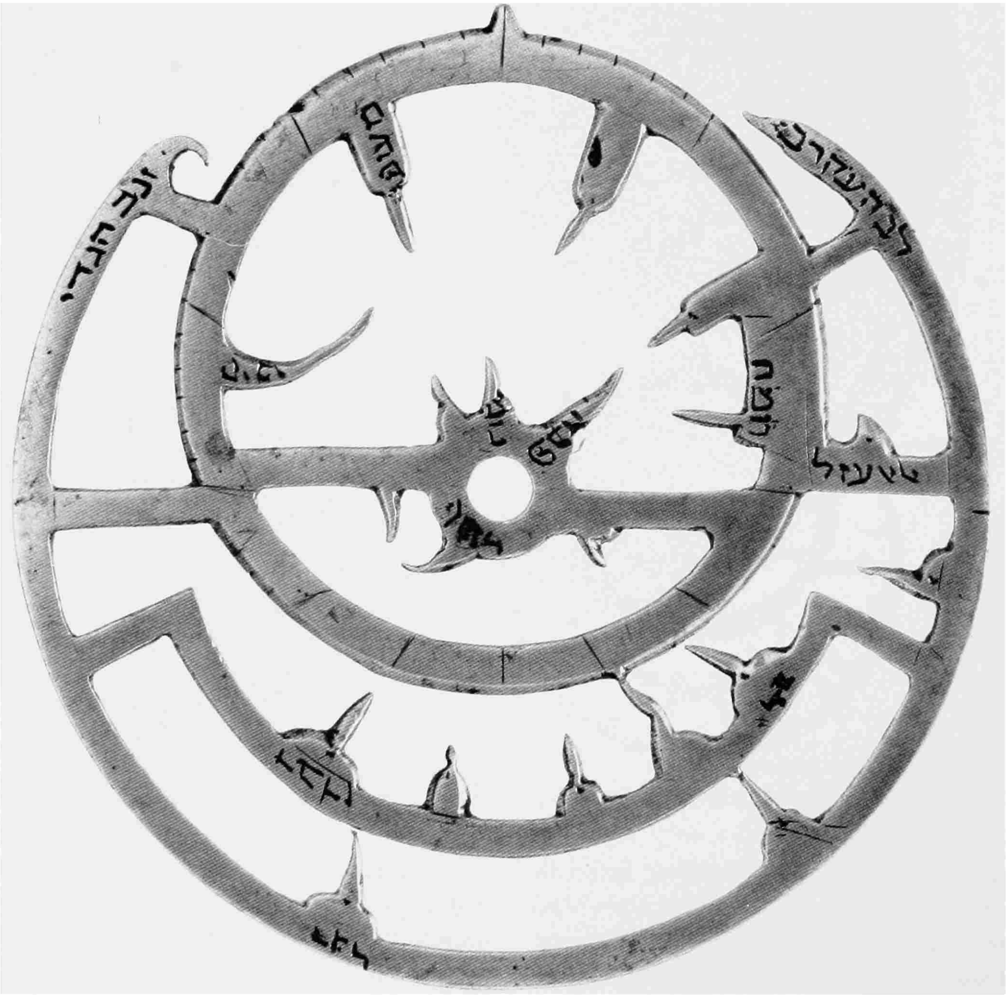


FIGURE 115.—Astrolabe No. 2572. Front view of ᶜ*ankabūt.*

FIGURE 116.—Astrolabe No. 2572. Back view of ᶜ*ankabūt* with inscription.

perimeter of the quadrants just inside the zodiacal scale. According to this calendar, the date of the vernal equinox is 15 March. The signature and date are engraved in the upper quadrants. Shadow squares divided into finger units fill the lower quadrants.

All faces of all five plates have been engraved with stereographically projected horizon, altitudes (every 6°), azimuths (every 10°), and unequal hours. In addition, prayer lines (*ash-shafaq*, *fajr*, *ẓuhr*, ᶜ*aṣr*) have been included on both plate faces of one plate (number 4). The unequal hours are not only identified by number words and symbols, but are also associated with the Arabic terms for animal (*ḥayawan*, hours 1, 4, 7, 10), mineral (*ma*ᶜ*dan*, hours 2, 5, 8, 11), vegetable (*nabat*, hours 3, 6, 9, 12), and male (*mudhakkarah*, hours 1, 3, 5, 7, 9, 11) and female (*mu*ᵓ*annathah*, hours 2, 4, 6, 8, 10, 12). Inscription on each plate face associates it with a geographic location as follows:

Plate	*Inscription*	
1a	[No latitude at the equator]	Hours 12
1b	ᶜ*arḍ*	66
2a	*li-Madinat aṣ-ṣīn* ᶜ*arḍuha*	18
2b	*li-Mecca*, [May God Honor it]	21 30
3a	[Medina of the Prophet, Peace upon him] *wa* ᶜ*arḍuha*	24
3b	*Akhmīn wa*ᶜ *arḍuha*	27
4a	*Qurṭubah wa* ᶜ*arḍuha*	33 30
4b	*Ishbīliyah* ᶜ*arḍuha Gharnāṭa*	37 30
5a	*al-Miria min al-iqlīm ar-rābi*ᶜ *wa*ᶜ *arḍuha*	36
5b	ᶜ*arḍ Saraqusṭa*	42

FIGURE 117.—Astrolabe No. 2572. Back view of disassembled astrolabe.

Inscription on these plates and on the body of the astrolabe is Arabic Kufic of the western type.

The rete of this astrolabe is of simple design, incorporating a complete, counterchanged east-west bar and a portion of equinoctial arc (outside the ecliptic). There are 22 star pointers. Twelve of these are inscribed with Hebrew star names; the remainder are blank. The ecliptic circle is divided by scratched lines. There is no inscription on it. Two star pointers are inscribed in Hebrew on the back of the rete. In addition, there is a single Hebrew word inscribed along the back of the ecliptic circle.

The pin is a short bolt with a flat head. A thin wire serves as wedge.

Remarks: This instrument is remarkable for a number of reasons. If the reading of the date is correct, it is the earliest astrolabe in the collection. The phrase *bi-Balansiya* follows the date. Saliba believes that it refers to the city of Valencia. One of the plates (number 4) is heavier than its fellows, and it exhibits a slightly different style of composition. The designation of the unequal hours found on all plate faces is rather unusual. It is unlikely that Muḥammad ben as-Sahli is responsible for the inscription currently found on the rete of this instrument. However, smoothed surfaces on the rete suggest that an inscription may have been erased to make way for the Hebrew, so the rete pattern may indeed be due to the originator. No alidade and no wedge are preserved with this instrument.

The maker is the younger member of a father-son team of instrument makers working in Valencia.[109] His name appears together with that of his father, Ibrahim ben Saʾid, on a globe finished A.H. 478 [1085], and preserved in the Museo di Storia della Scienza in Florence.

CCA No. 3643

(FIGURE 118)

Date: Not legible.

Signature: Not legible.

Components: Body with throne, handle, ring, six plates, rete, alidade, pin, and wedge.

Diameter: 118 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch. It is pierced with four holes, placed symmetrically on either side of the handle hole. The handle is stirrup-shaped; the ring has no visible seam. A scale of 360° has been engraved on the rim; it has been subdivided into units of 6° and 1°. The front central area contains stereographically projected altitudes (every 6°, uninscribed), azimuths (every 5°), and a prayer line (*az-zawāl*) for latitude 90°.

The outer margin of the back contains four altitude scales. The inner margin contains a scale of zodiacal divisions and a concentric calendar scale. The date of the vernal equinox is 14 March. The two upper quadrants contain an illegible inscription in Naskhi script. A barely legible date and an illegible signature are inscribed in the lower quadrants below two shadow squares.

Each of the six plates includes a tooth (at 90°). All but two plate faces contain stereographic projections of a horizon, altitudes (every 6°) and azimuths (every 10°), unequal hours, and prayers (*shafaq*, *fajr*, *az-zawāl*, *ẓuhr*, *ʿaṣr*). The projections are identified as follows:

Plate	*Latitude*	
2a	*li-ʿarḍ Miṣr wa kull balad ʿarḍuhu*	30 00
2b	*li-ʿarḍ Menerah wa kull balad ʿarḍuhu*	39 00
3a	*li-ʿarḍ al-Iskandaria wa kull balad ʿarḍuhu*	31 00
3b	*il-ʿarḍ ʿAsqalān wa kull balad ʿarḍuhu*	34 00
4a	*li-ʿarḍ Marākesh wa kull balad ʿarḍuhu*	31 30
4b	*li-ʿarḍ Qurṭubah wa kull balad ʿarḍuhu*	38 00
5a	*li-ʿarḍ Fās wa kull balad ʿarḍuhu*	33 40
5b	*li-ʿarḍ Falastīn wa kull balad ʿarḍuhu*	32 30
6a	*li-ʿarḍ Ishbīliyah wa kull balad ʿarḍuhu*	37 00
6b	*li-ʿarḍ Ṭulaiṭilah wa kull balad ʿarḍuhu*	40 00

Some prayer lines on these faces are hatched. Of the two remaining plate faces, one contains stereographically projected horizon, altitudes (every 5°), and azimuths (every 6°) for latitude 66°; the other contains horizons and altitudes for latitude 0°; it is inscribed *li-jāmiʿ al-ʿurūḍ*. The inscription on all plates is Arabic Kufic maghribi.

The rete includes 26 bent dagger-shaped star pointers, each inscribed with a star name. The ecliptic is subdivided into 6° units. The inscrip-

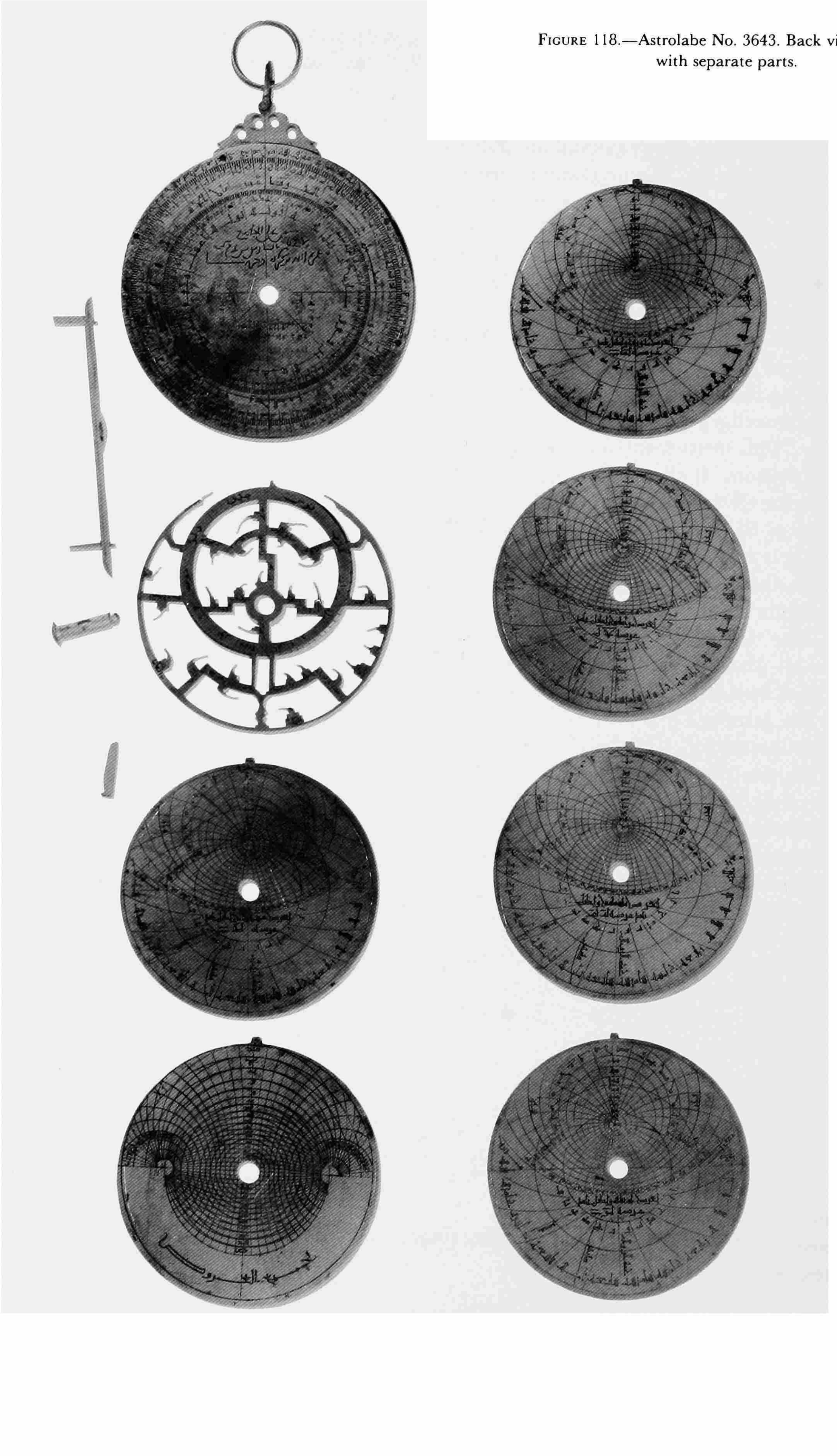


FIGURE 118.—Astrolabe No. 3643. Back view of body with separate parts.

tion on both star pointers and ecliptic is Arabic Naskhi. The rete's pattern incorporates a counterchanged east-west bar, an interrupted and counterchanged meridian, and upper and lower sections of equinoctial arc. The uninscribed alidade is not counterchanged. It has a central semicircle, beveled diagonal edges, and a beveled fiducial line. The sighting plates are each pierced with a single hole. The pin is a bolt with a flattened semicircular head and a doorknob tip. The wedge is a simple rectangle.

Remarks: The titles of the shadow square scales on this instrument have been inscribed *inside* the squares. Both digits and words identify the divisions of the unequal hour scales on all plate faces inscribed with such a scale. Some altitudes and azimuths on all plates are emphasized using hatched lines. The fact that the rete is inscribed in a hand different from that of the body places its origin in doubt. The simplicity of the alidade suggests that it may be a replacement. In his discussion of this instrument, Gunther[110] translates the modern Arabic inscription on the back as follows: "Bestowed on the Greatest Mosque the 6th of Muharram year 1308."

CCA No. 3811

(FIGURES 119, 120)

Date: Ca. A.D. 1850.

Signature: None.

Components: Body with throne, handle, ring, four plates, rete, alidade, pin, and wedge.

Diameter: 111 mm.

Material: Brass.

Characteristics: The relatively broad, Moorish arch-shaped throne is uninscribed and undecorated, except for a geometric design etched on the back face. The handle is stirrup-shaped. There is a heavy ring. The rim is divided into a scale of 360° with the first unit marked "5" and the last unit marked "360" in *abdjad* numerals. Inside the front central area, there is a tooth at 270°. There is also a gazetteer listing 52 places with longitude, latitude, azimuth of the Qibla, and direction of azimuth of the Qibla for each.

Altitude scales divide the upper margin on the back of the astrolabe. The lower margin contains cotangent scales divided into feet (left) and fingers (right). There is a scale of stereographically projected declination arcs in the upper right quadrant. Seven lines, marking the azimuth of the Qibla for various locations, have been graphed on these declination arcs. These locations include Medina (top), Baṣra, Iṣfahan, Ṭus, Qandahar, Shustar, and Multan. For a transcription of the inscription relating to this scale inside the innermost declination arc, see the description of No. 63. There are sines at sexagesimal intervals in the upper left quadrant. Shadow squares divided into feet (left) and fingers (right) occupy the lower quadrants. There is a scale of triplicities inside the squares. The natures are identified using Arabic words. Outside the squares, there are two semicircular astrological scales: a scale of the zodiacal signs, and a scale of lunar mansions. Three other concentric bands have been engraved in these lower quadrants. They are divided but not inscribed. There is a geometric design along the edge of the instrument similar to that etched on the back of the throne.

This astrolabe is fitted with four plates. Three of these are notched at 270°. One has notches at 0°, 90°, 180°, and 270°. The plate with four notches contains 30 quarter horizons on one face, representing every 2° of latitude from 10° through 66°. This face also contains four declination scales, one at each notch. The other face of this plate contains only stereographically projected tropics and equator. The remaining plate faces contain stereographically projected coordinates for a single latitude. One of these (4b) has only altitudes (every 6°) and azimuths (every 10°). One plate face (3a) has altitudes (every 3°), azimuths (every 10°), and unequal hours. One plate face (3b) has altitudes (every 3°), azimuths (every 10°), unequal hours, equal Italian hours, and a prayer line (marked *samt Qiblat Ṭūs*). Three plate faces contain altitudes, azimuths, unequal hours, and equal Italian hours. The plates are inscribed with the following latitudes:

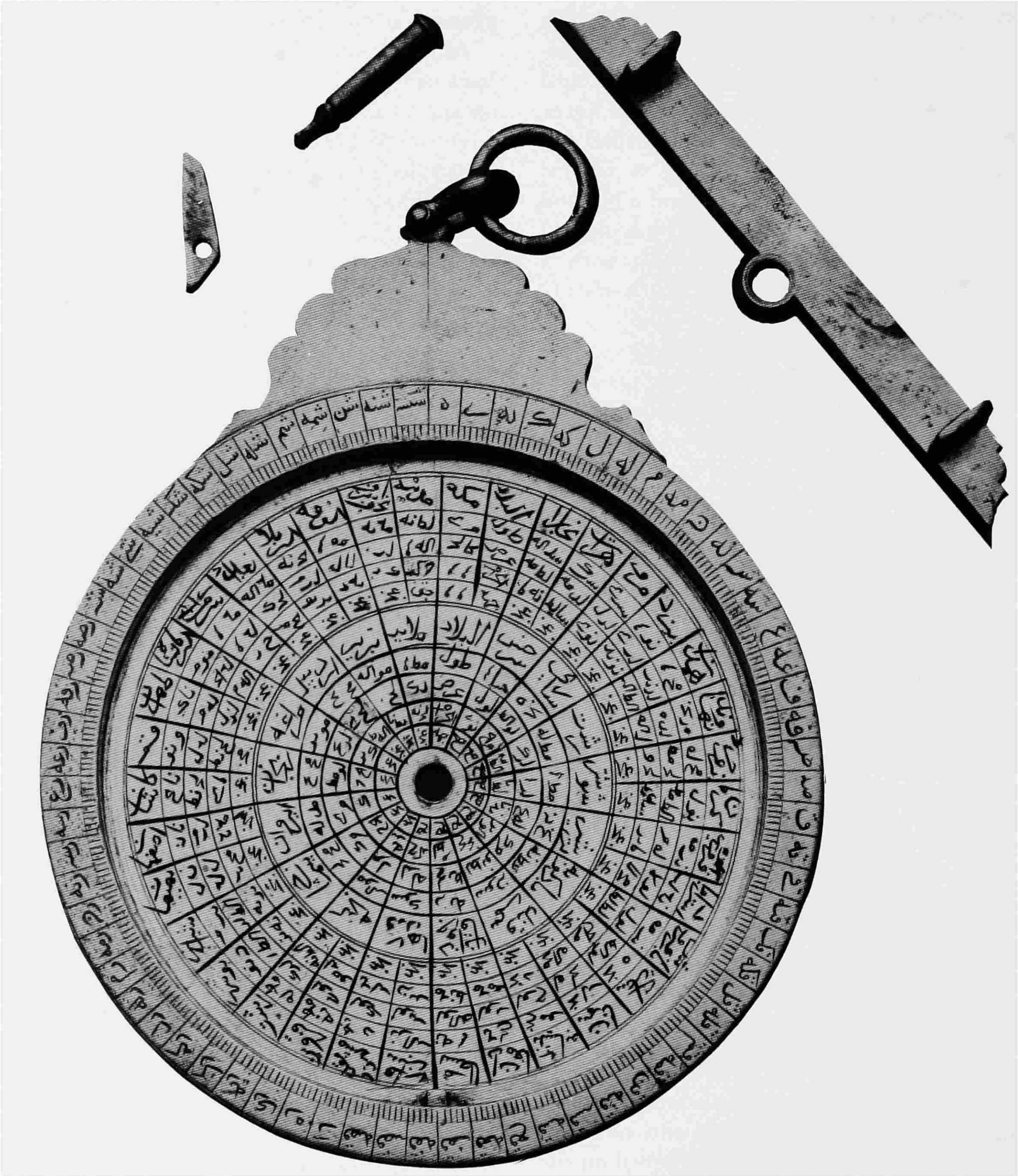


FIGURE 119.—Astrolabe No. 3811. Gazetteer.

Plate	*Latitude*		*Length of daylight*	
2a	*ʿarḍ*	29	*sāʿātuhu*	13 42
2b	*ʿarḍ*	32	*sāʿātuhu*	14 07
3a	*ʿarḍ*	34	*sāʿātuhu*	14 17
3b	*ʿarḍ*	37	*sāʿātuhu*	14 32
4a	*ʿarḍ*	36	*sāʿātuhu*	14 28
4b	*mīzān al-ʿankabūt*			

The rete pattern consists largely of curling vines, which frame a bird-like figure just above the center. There is a complete equinoctial bar with one counterchange. There are 34 inscribed star pointers. The ecliptic is subdivided into units of 6°. Colures, tropics, and equator have been engraved on the back of the rete. The alidade is

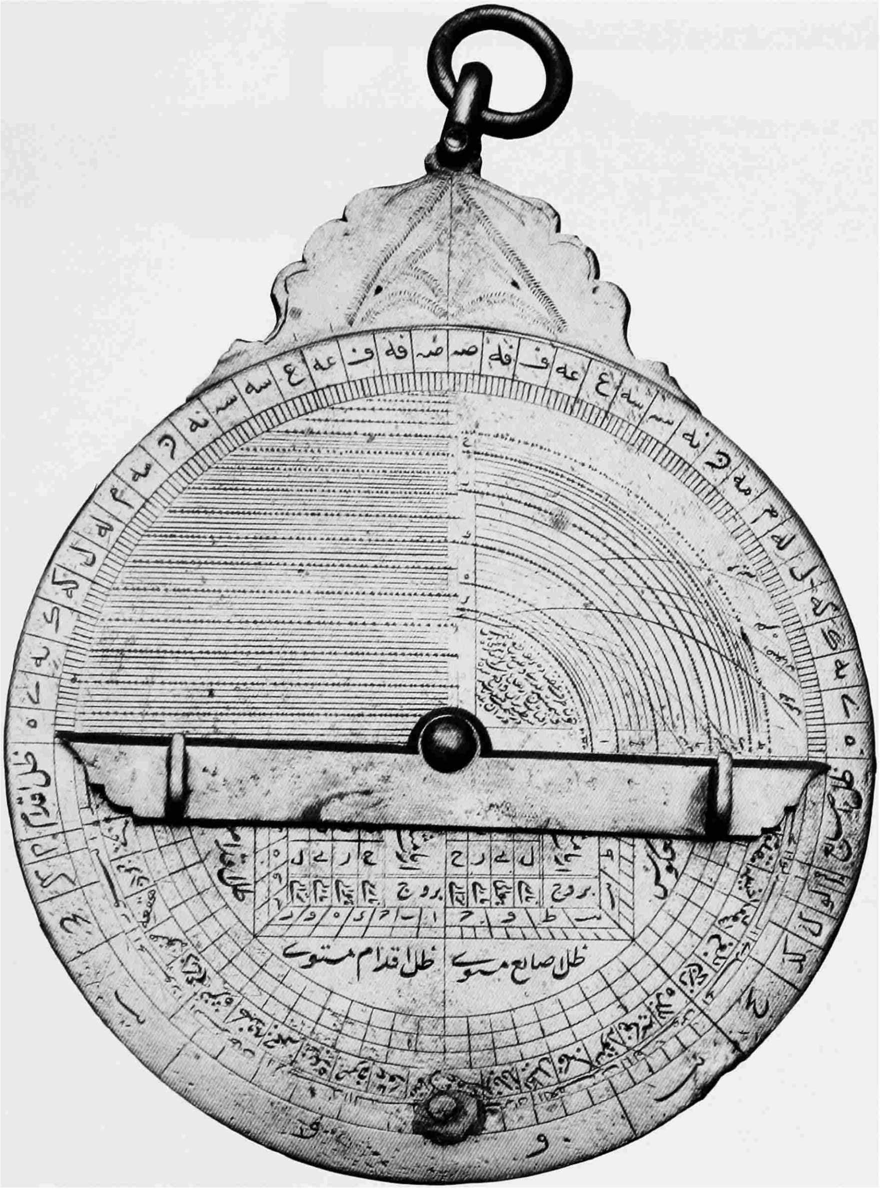


FIGURE 120.—Astrolabe No. 3811. Back view.

not counterchanged. It is neither decorated nor inscribed. There are two holes in each sighting plate. The pin is a bolt with hemispherical head and tapered tip. The wedge is an amorphous shape pierced by a small hole.

The alphabet employed by this maker is Arabic Naskhi.

Remarks: The longitudes in the gazetteer have been measured from Greenwich. Similarly measured and arranged longitudes can be found on No. 63. The maker uses dotted lines to emphasize some division lines in the upper quadrants on the back of the astrolabe. There are also some dotted lines on the plates.

CCA No. 4000

(FIGURES 121, 122, 123)

Date: 1861 [1805] (see "Remarks").
Signature: Virabha (Vitrabhadra).

FIGURE 121.—Astrolabe No. 4000. Inscribed edge.

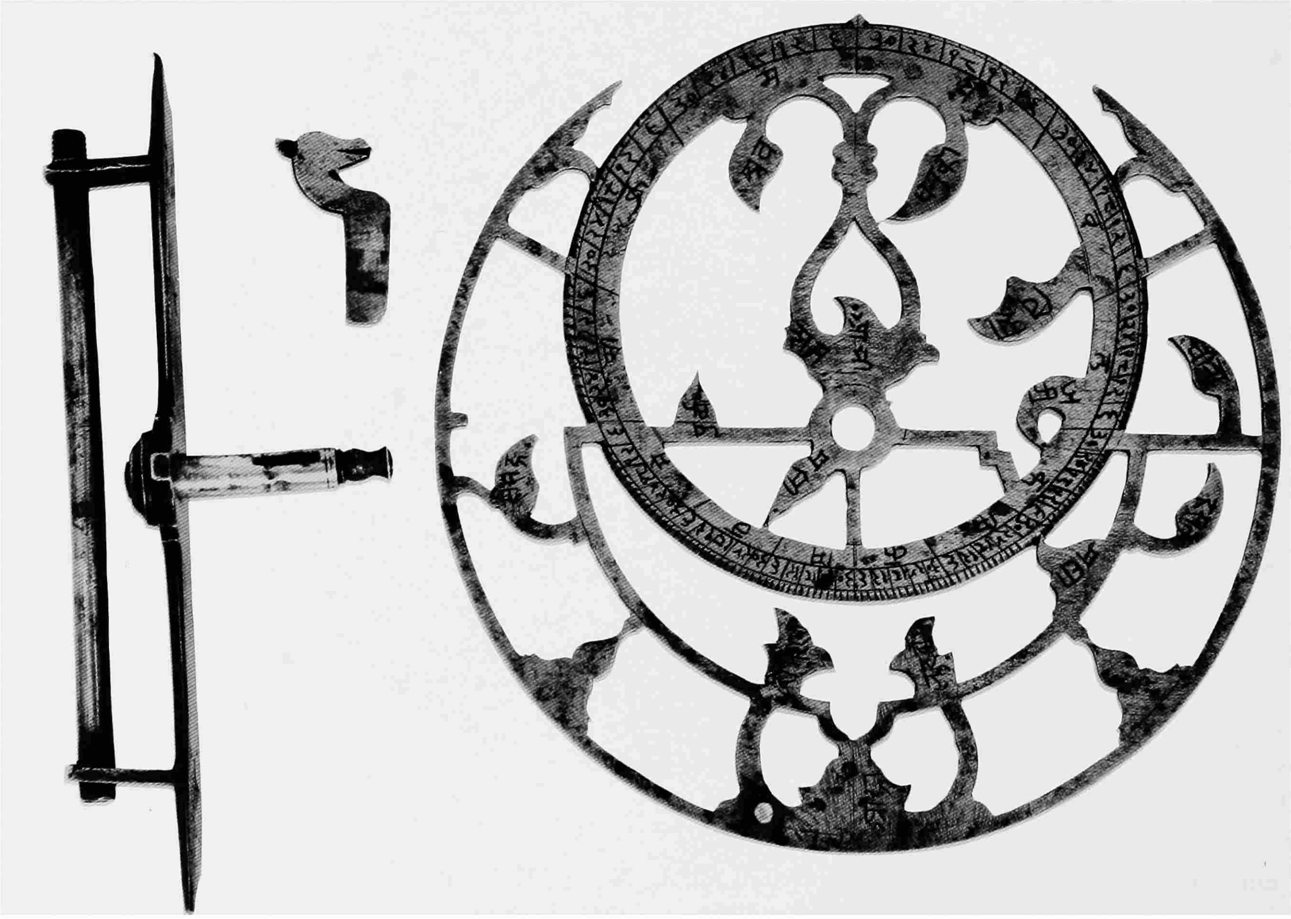


FIGURE 122.—Astrolabe No. 4000. Rete.

Components: Body with throne, handle, ring, eight plates, rete, alidade with sighting tube, pin, and wedge.

Diameter: 141 mm.

Material: Brass.

Characteristics: The throne has the shape of a high Indian arch. The signature and date are inscribed on the front in Arabic. The handle is stirrup-shaped, with a diamond-shaped cross-section. The ring has a circular cross-section. The rim is divided by a scale of 360° divided into units of 6°. The first unit is marked "1;" the last

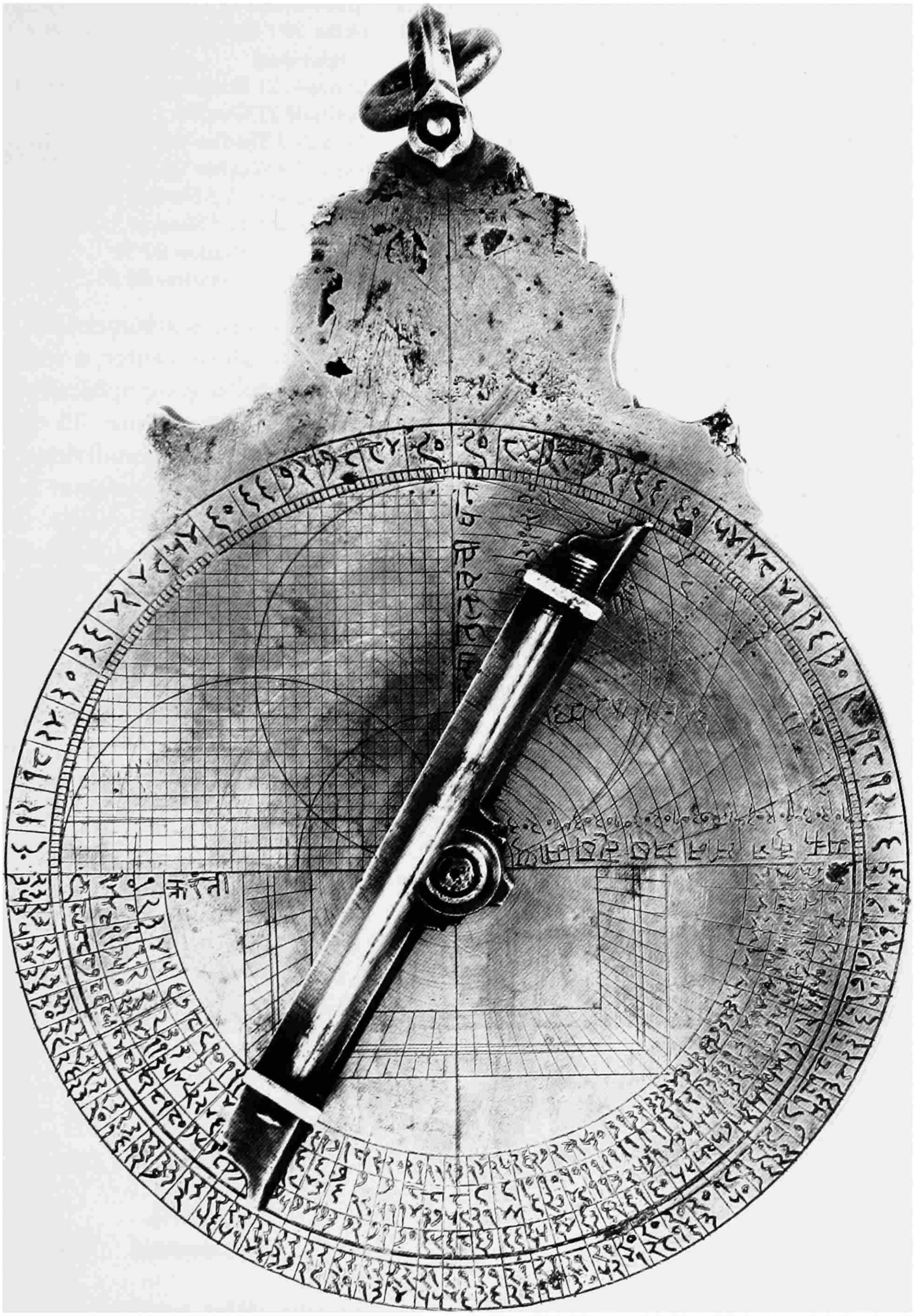


FIGURE 123.—Astrolabe No. 4000. Back view.

unit, "60." A tooth projects into the front central area at 90°. The front central area has been divided by concentric circles and radial lines. The maker may have intended to include a gazetteer, but has filled one concentric band only, with the following inscription in Sanskrit: "The headman Sri Rama, government of the town of Jodhpur, 1235 [1819]."

On the back of the astrolabe, the upper margin contains altitude scales. The upper right quadrant contains equally spaced declination arcs. Engraved on these arcs are lines representing the unequal hours and two prayer lines. In addition, there are two engraved semicircles and two engraved quarter circles. Sines and cosines have been engraved at sexagesimal intervals in the upper left quadrant. There are shadow squares in the lower quadrants divided into feet (left) and fingers (right). Outside these squares are four semicircular scales. Two of these give measures of solar declination; two record right ascension. Together the scales relate solar declination to every degree of right ascension. There are two scales engraved on the outer edge of this astrolabe, each divided into 46 units. The divisions of the first of these are inscribed with the even numbers from 2 to 90. The divisions of the second are inscribed as follows: 343 39 (adjacent to 2), 181 36, 114 08, 85 23, 68 03, 46 27, 48 48, 40 26, 36 42, 32 58, 30 00, 27 00, 24 36, 22 10, 20 30, 18 40, 17 34, 16 31, 15 21, 14 00, 13 19, 12 06, 11 36, 10 48, 10 07, 9 22, 8 43, 8 06, 7 30, 6 52, 6 23, 5 51, 5 25, 4 50, 4 22, 3 54, 3 26, 3 00, 2 32, 2 16, 1 41, 00 50, 00 38, 00 12, 00 00 (adjacent to 90), 12 (adjacent to a division inscribed with an illegible character).

The instrument has been fitted with eight plates. Each of these is notched at 90°. Plate face 1a contains only quarter horizons (41), representing every degree of latitude from 10° to 67°. Plate 2a contains, in each of four quadrants, stereographically projected altitudes (every 6°) for a single latitude. All remaining plate faces contain the following stereographically projected coordinates: altitudes (every 6°), azimuths (at various intervals), unequal hours, and equal Italian hours. The following latitudes, locations, and parameters are inscribed on the plate faces:

Plate	*Inscription*
1b	Latitude 26 Ajmer / Shadow 5 50
2a	[UL] Latitude 48 / Shadow 13 50; [UR] Latitude 60 / Shadow 20 3; [LL] Latitude 42 / Shadow 11 10; [LR] Latitude 52 / Shadow 15 50
2b	Kuruksetra [=Panipet] 30 / Shadow 06 55
3a	Tilanqa 18 / Shadow 03 55 Longest Daylight 32 (ghatikas)
3b	Daulatabad 20 / Shadow 04 20
4a	Ahmadabad 19 / Shadow 04 18
4b	Delhi 29 / Shadow 06 40 Longest Daylight 34 34 (ghatikas)
5a	Latitude 21 Burhanpur / Shadow 04 30
5b	Latitude 27 Gwalior / Shadow 05 35
6a	Agra 27 / Shadow 06 06; Mecca 22 / Shadow 04 04
6b	Agra 27 / Shadow 06 06
7a	Nepalapura 31 / Shadow 06 20
7b	Samarqand 40 / Shadow 11 23
8a	Lahore 32 / Shadow 07 31
8b	Kashmir 35 / Shadow 08 03

The rete pattern is symmetrical. It includes a bird figure just above center, a straight equinoctial colure, and a stereographically projected celestial equator. There are 15 inscribed star pointers. The ecliptic is subdivided into units of 6° and 2°. Tropics and equator have been engraved on the back of the rete. There are no counterchanges in the alidade. Neither are there markings of any kind. The sighting device includes a tube which connects the sighting plates. Each of these latter is pierced with two holes. The pin is a bolt with bell-shaped head and doorknob-shaped tip. The wedge is rectangular.

Remarks: Inscription of the divisions of the ecliptic consists of the first two letters of the Indian names of the zodiacal signs. The "shadow" parameter given on the plates is the length in digits of the noon equinoctial shadow of a 12-digit gnomon at the given latitude. The date inscribed on the instrument is a year in the Vikrama era which began in 57 B.C. Hence, the equivalent date in the Gregorian calendar is A.D. 1805.

CCA No. 4001

(FIGURES 124, 125)

Date: A.H. 621 [1224].

Signature: Muḥammad ben Fattuḥ al-Khamaʾiri.

Components: Rim with throne laminated to backplate with throne, handle, four plates, pin, and wedge.

Diameter: 184 mm.

Material: Brass.

Characteristics: The throne is shaped like a Moorish arch pierced with two small holes. The

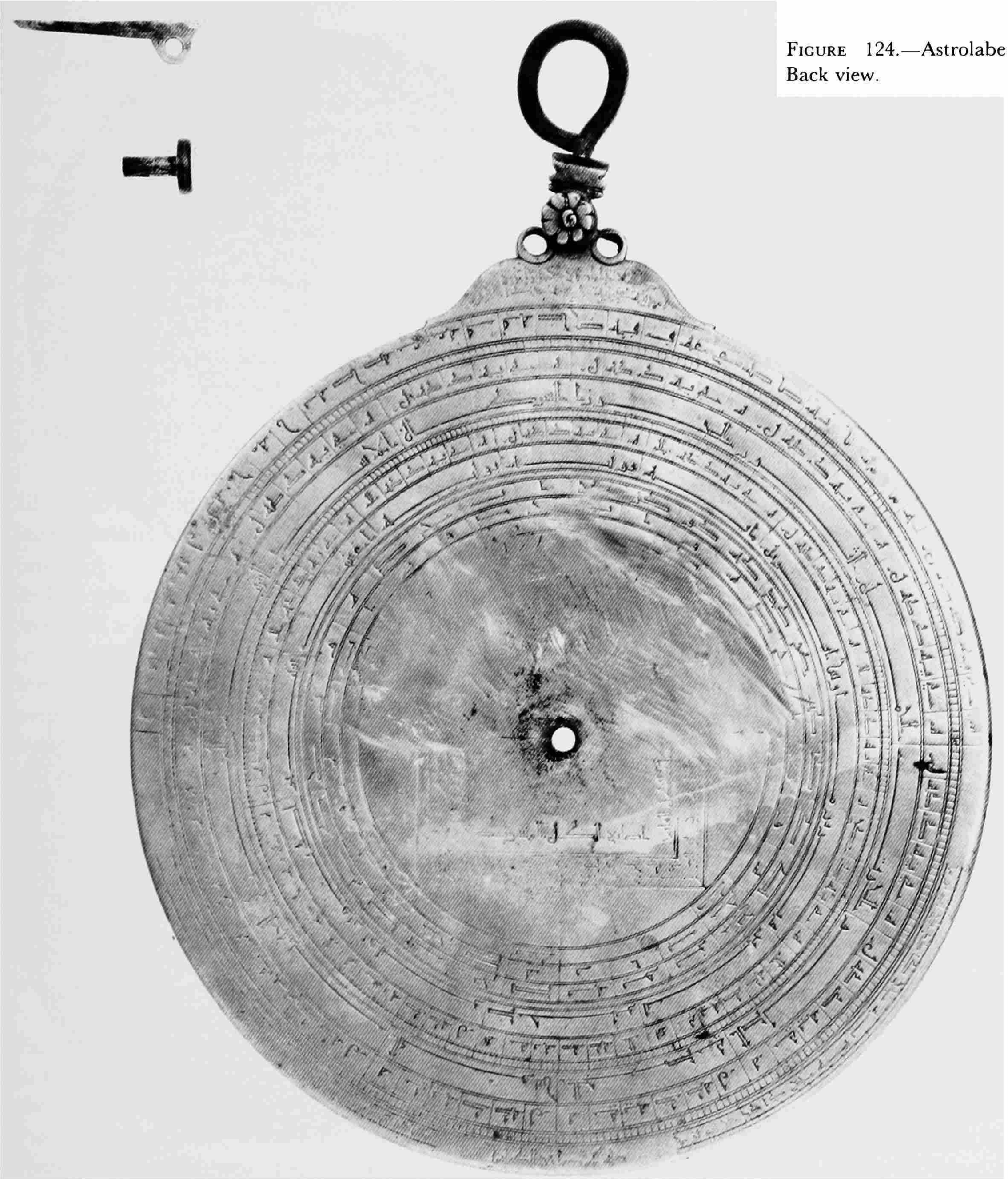


FIGURE 124.—Astrolabe No. 4001. Back view.

front is decorated with an engraved geometric design. The back is inscribed with the maker's signature and date. The stirrup-shaped handle is decorated with rosettes at the end of the cross-bar. A geometric design decorates its top. A scale of 360° divides the rim. A stereographic projection of altitudes (every 3°) and azimuths (every 6°) for latitude 66° fills the front central area. On the back of the astrolabe, the margin is divided by two altitude scales (upper portion) and two cotangent scales in finger units (lower portion). A scale of zodiacal divisions (in units of 1°, 5°, and 30°) and a concentric calendar scale (divided into units of days, groups of five, six, or eight days,

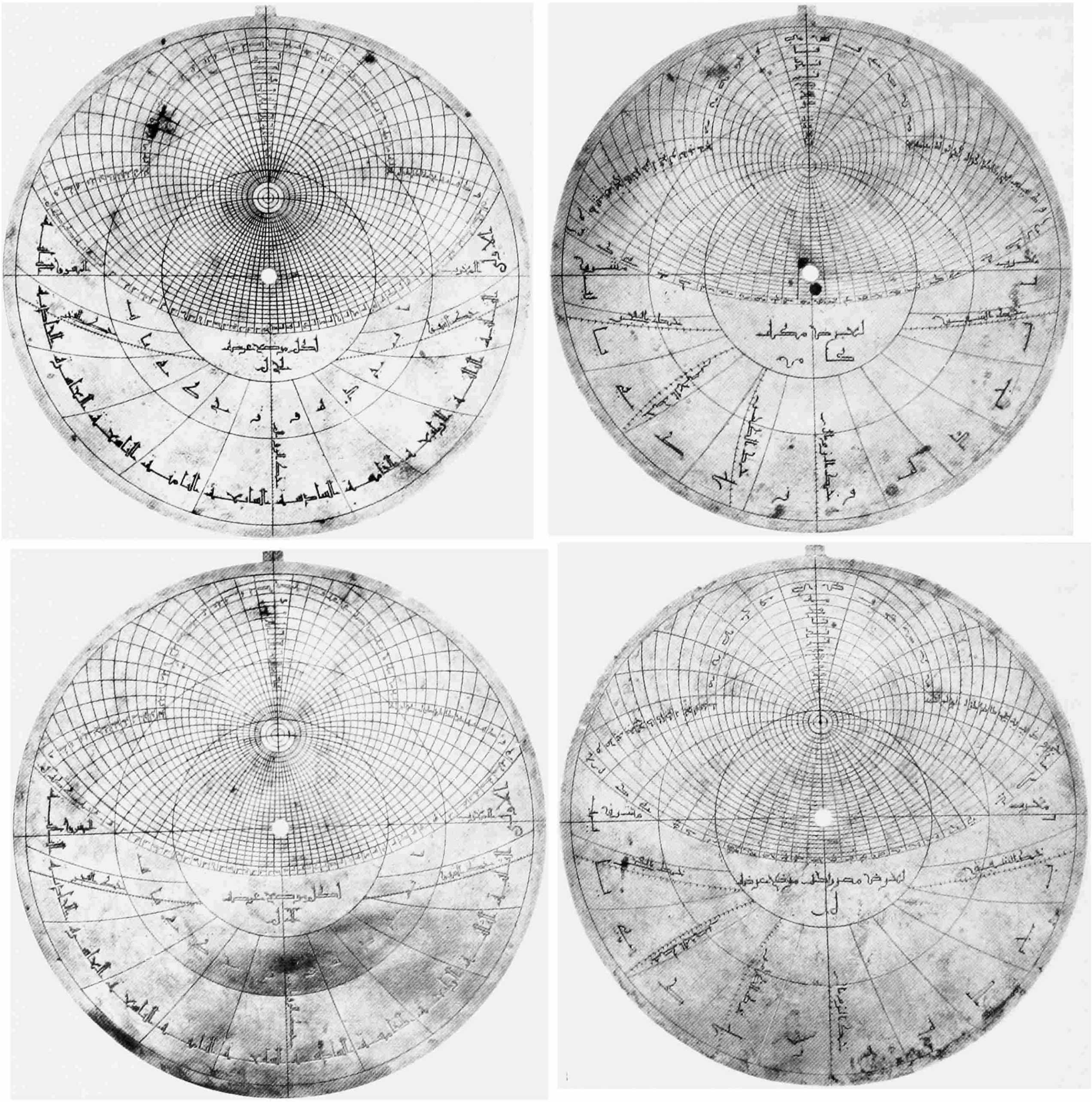


FIGURE 125.—Astrolabe No. 4001. Plates for latitudes 38°30′ (upper left), 21°40′ (upper right), 31°30′(lower left), and 30° (lower right).

and months) are inscribed just inside the outer margin. The date of the vernal equinox is 14.9 March. Just inside the calendar scale there have been engraved three scales designed to assist in calendric computation. These are a solar cycle (28 divisions), a scale of days of the week corresponding to the solar cycle (28 divisions), and a scale of leap year designations (28 divisions). The upper quadrants contain no inscription. The two lower quadrants contain shadow squares divided into finger units.

This astrolabe is fitted with four plates. Each includes a tooth at 90°, and each is inscribed with stereographically projected horizon, altitudes (ev-

ery 3°), azimuths (every 10°), unequal hours, and prayers (on plates 1a, 2, and 4a: *ash-shafaq*, *az-zawāl*, *aẓ-ẓuhr*, *al-^{c}aṣr*, *al-fajr*; on plates 1b, 3, and 4b: as above, but no *aẓ-ẓuhr* and *al-^{c}aṣr*). The projections are identified by the following inscription:

Plate	*Inscription*	
1a	*li-^{c}arḍ Mecca*	21 40
1b	*li-^{c}arḍ Medina al-Musharrafah*	25 30
2a	*li-^{c}arḍ Miṣr wa li-kull mawḍi^{c} ^{c}arḍuhu*	30 00
2b	*li-^{c}arḍ Miknāsa az-zītūn wa li-kull mawḍi^{c} ^{c}arḍuhu*	34
3a	*li-kull mawḍi^{c} ^{c}arḍuhu*	31 30
3b	*li-kull mawḍi^{c} ^{c}arḍuhu*	36 30
4a	*li-kull mawḍi^{c} ^{c}arḍuhu*	33 30
4b	*li-kull mawḍi^{c} ^{c}arḍuhu*	38 30

Most of the inscription is Arabic, Kufic maghribi; but on two of the plates (numbers 3 and 4) some Naskhi has been scratched near the meridian.

The pin is a bolt with a flattened head. The wedge is a bird with a pierced eye.

Remarks: The plates included with this instrument are remarkably varied. Plates 1 and 2 appear to consist of cast metal, and plates 3 and 4 appear to have been rolled. Plate color varies as well: number 1 is a dark golden color, 2 and 4 are the color of yellow gold, and 3 is copper colored. On all of the plates the prayer lines are jagged. A few other jagged lines designate altitudes (about every sixth) and azimuths (prime meridian) on all plates but the third. There are obvious construction guidelines on all plates. The rete is missing.

A second astrolabe made by Muḥammad ben Fattuḥ in A.H. 621 (CCA No. 130) is quite similar to this example. It is preserved in the Museum of the History of Science, Oxford. Another of ben Fattuḥ's astrolabes, in the collections of the Adler Planetarium, Chicago (CCA No. 153), is dated A.H. 634. Ben Fattuḥ's signature on the Smithsonian instrument identifies him with the city of Seville in Spain.

CCA Nos. 4002, 4003

(FIGURES 126, 127)

Diameter: 80 mm (4002), and 103 mm (4003).

Remarks: These two objects are examples of pseudo-astrolabes. They each have all of the components of authentic instruments (body with throne, handle, three plates, rete, alidade, pin, and wedge), but claims to authenticity do not extend beyond form. For example, divisions of the rim number 44 in the one case (No. 4002) and 56 in the other (4003). Inscription in the front central area of each looks like a gazetteer but hardly reads like one. No notch or tooth holds the plates fixed. There are, in each case, four circular scales on the back. Only one of these is recognizable, consisting of pictures representing the zodiacal signs. There is a rectangular "scale" composed of four rows and four columns inside these circles. The maker may have seen the back of an astrolabe, but he almost surely did not understand it. The lines on the plates in some cases form a floral design. In no case do they correspond to stereographically projected coordinates. The retes exhibit amateur workmanship. No recognizable star

FIGURE 126.—Astrolabe No. 4003. Front view.

FIGURE 127.—Astrolabe No. 4002. Back view.

names appear. In the one case (No. 4002) the ecliptic is divided into 19 units: in the other (No. 4003) it is divided into 26 units. The markings on each alidade have no significance. There are no sighting holes in the "sighting plates." All the inscription employs Hebrew letters, perhaps to make it less accessible to prospective buyers. It appears likely that the same anonymous maker is responsible for both objects.

CCA No. 4004

(FIGURE 128)

Diameter: 140 mm.

Remarks: This object, like entry Nos. 4002 and 4003, exhibits the characteristics of a pseudo-astrolabe. An irregularly divided rim; a "gazetteer," which lists place names without geographic parameters; loose, indistinguishable plates; a zodiacal scale incorporating pictures; and a symmetrical rete without recognizable star names—all preclude the object's identification as a functioning scientific instrument. Although the alidade of this object includes sighting plates pierced with holes, there is no altitude scale against which "sightings" can be measured. To the casual observer, the scales and tables on the back of the instrument look functional; but closer examination reveals that with the exception of the zodiacal scale, no useful astrological information is conveyed. The maker has used the Arabic alphabet and Naskhi script to decorate the object with numbers, and recognizable names of places and zodiacal signs. The placement of the inscription, however, combines with other clues to suggest that although the maker may have seen a functional astrolabe, he did not understand it.

FIGURE 128.—Astrolabe No. 4004. Back view.

Appendix I

Gazetteers

One faces a number of problems in attempting to transcribe cities written in the Arabic alphabet into a European alphabet. One can adopt a "generally accepted spelling" (such as that found in the *Times Atlas of the World*) or one can choose a phonetic representation which somehow accounts for etymological quirks and native shifts of sounds that have no equivalents in the European alphabet. The city names that appear in the tables in this Appendix represent an effort to preserve the intent of the native scribe without losing any geographic information. Whenever the spelling in the *Times Atlas* could be considered a faithful transcription of the Arabic city name, it was adopted as the standard spelling. The list that follows Table I.A. identifies deviations from the standard spelling and probable spelling errors. (An asterisk preceding the place name in the table indicates that it is annotated in the list.) When adoption of a *Times* standard would misrepresent the Arabic or when no *Times* standard could be identified, a phonetic transcription of the Arabic was included in the table. An effort was made to identify puzzling place names in works of prominent Arabic geographers.

The task of transcribing the geographic coordinates associated with a place named in the gazetteer of an astrolabe presents no fewer problems than the task of transcribing the place name itself. Whether written in Kufic or Naskhi, certain Arabic numbers are easily misread. For example, only the presence of a dot or the length of a stroke distinguishes the numerals 15, 35, and 55. Similar problems arise in relation to the numerals 45, 85, and 105. In general, numbers between 11 and 19 can be confused with numbers between 31 and 39 and with numbers between 51 and 59. In addition, numbers between 41 and 49 can be confused with numbers between 81 and 89 and between 101 and 109. Moreover, it is often difficult to distinguish numbers between 101 and 109 from numbers between 111 and 119. The convention for representing zero can easily be read as the number 45.

The information included in the gazetteers of the astrolabes from the National Museum of American History is presented in three tables.

Table I.A. summarizes all of the geographic information appearing on the instruments. The table is annotated to report Saliba's research on citations in the Arabic geographic literature and to indicate readings that vary from the listed parameters.

Wherever the information can be ascertained from the instruments, the table includes geographical longitude (in degrees and minutes), latitude (in degrees and minutes), azimuth of the Qibla (in degrees and minutes), distance from Mecca (or *al-masāfat* measured in *farsakhs*), and direction of the azimuth of the Qibla with respect to the four cardinal points (the *jihāt*).

The following symbolism has been adopted:

A = Name and geographic parameters appear on the instrument as listed in the table.

V = Geographic parameters on the instrument vary from those listed in the table. The reader is referred to the note associated with the place name for information about the nature of the variation.

R = Geographic parameters rounded to the nearest degree (for the rounded values see Table I.B.).

G = Geographic parameters measured from Greenwich Observatory (for these parameters see Table I.C.).

? = Problematic reading or identification.

– = Tentative identification.

* = Annotation in the list following the table.

Numbers in parentheses following the CCA numbers indicate the number of geographic parameters included in the gazetteer (e.g., (2) = longitude and latitude).

TABLE I.A.—Place names and geographic parameters from the gazetteers

Place name	Longitude	Latitude	Azimuth	Distance	Direction	CCA No. (parameters)																													
						15(3)	25(4)	31(4)	37(4)	39(4)	40(3)	42(3)	44(4)	47(3)	49(3)	52(3)	53(4)	55(3)	57(3)	58(3)	59(4)	61(4)	62(4)	63(4)	64(3)	65(4)	66(4)	70(1)	85(2)	86(2)	87(2)	88(2)	2566(3)	2569(2)	3811(4)
ʿAbadan	84 30	30 00																											A						
* ʿAden	76 00	11 00																											A					V	
* ʿAmuriyyah	64 00	43 00																											A						
* ʿAsqalan	66 30	32 15																											A						
* Abarquh	88 10	31 30	45 00			A																													
* Adhoun	93 30	35 20	11 23		SW					A						V		V																	
* Agra	114 00	27 13	91 00		SW					V			R					V							A				A				A		
* Aḥmadabad	108 40	23 15																												A	V	A		A	
Aḥmadankar	105 00	19 00																																A	
Ahwaz	85 00	31 00	40 30													A			A																
* Ajmireh	111 05	26 00																											V	V	V			A	
* Akbarabad	115 00	26 43																												A	V			A	
* Akhlat	75 50	39 20																											A						
* Allahabad	105 34	26 50																													A				
* Al-lan	83 00	44 00																											A					A	
* Al-Rum	77 00	39 40																													A				
* Amid	73 40	38 00																											A						
* Amol	88 20	36 05	34 37	393					A		A	V	R			V	A			V								V					A		
* Amol Qaṣabat T.	88 20	36 15																														A			
Arbil	77 20	35 00																											A						
* Ardabil	82 30	38 00	17 13		SW		V	V	A	V	A	A	R	A	A	V		A		A	V	V		G	V	A		A	A		A	V	A		G
* Arḍ Rum		39 40																										A							
Arz al-Rum	77 00	39 40																											A						
Asker Makarram	84 30	31 15																																A	
* Asku Qaṣabat J.	89 30	37 55																														A			
* Asterabad	89 35	36 50	38 48	411	SW		V	A	A	V	A	A	R	V	V	A	A	A	A	V	A	A	A	G		A	V		V			A	V		G
* Awadh	108 06	27 22																												A				A	
Ba ʿalbek	70 45	33 15																											A					A	

* Bab al-Abwab	85 00	33 00																												A			V			
* Babulghar	83 30	39 50																												A						
* Badakhshan	104 24	37 10	64 09		SW					V					V	V		V		A									A	A		A		A	
* Badhaghis	84 30	35 20	43 00																	A															
Badkuba	29 55	40 20	26 17																																G
* Baghdad	80 00	33 25	12 45	242	SW	V	V	A	A	A	A	V	R		V	V	A	A	V	A	V	V		G	-	V	V	A	V	A	A		A	V	G
Bahihan	50 30	30 35	48 12		SW																			G											G
Baḥrain	83 00	25 15	57 23													A													A				A		
* Bait al-Maqdis	66 30	31 50	45 56		SE		V			A			R					A		V	V	V		G					A	A				A	
* Bakar	85 00	27 40																												A				A	
* Bakouyeh	84 30	39 30																														A		A	
* Balkh	101 00	36 41	60 36		SW		V						R			A				A								A	A	V	A	A		V	
* Banaras	107 20	26 55																												A		V		A	
* Barda^c	83 00	40 30	16 27	214	SW							A									V	A							A					A	
Barda^cah	83 00	40 30	16 27		SW																											A			
* Barfurush	86 50	36 50	34 17		SW															V	A	V	V	G		V									G
* Baṣra	84 00	30 00	37 59	229	SW		V	V	V	V	A	A	R		V	V	V	V	V	V	A	V				V	V		A	V	A		V	A	
* Basṭam	89 30	36 10	39 13		SW				V	V	V	A		V	V	V		V		A	V	V	V	G	-	V				A			V		G
* Bijapur	105 30	17 20																												A	A	A		V	
* Biyar	89 10	35 00	45 06																	A															
Borujerd	83 00	34 00	24 00																	A															
* Broach	111 05	21 20																												A					
* Budaun	114 59	27 32																												A				A	
* Bukhara	97 30	39 50	45 48		SW	V				V					V			A		A				G				V	A	A	A	A	V	A	G
* Bulghar	90 00	49 30																											A		A			A	
* Burhanpur	109 00	20 31																											A	V	A			V	
Bust	100 00	33 00	68 30													A																			
* Daibul	102 30	25 10																												A				V	
Daibul wahu Tbt	102 07	25 10																														A			
* Damavand	87 20	36 20	30 00																	A															
* Damghan	88 55	36 20	38 05		SW		V	V	A	V	V	V	R	V	V			V	V	V	V	V	V	G		V									G
* Daulatabad	83 20	34 10	24 40																	A										V				V	

TABLE I.A.—Continued

Place name	Longitude	Latitude	Azimuth	Distance	Direction	CCA No. (parameters)																													
						15(3)	25(4)	31(4)	37(4)	39(4)	40(3)	42(3)	44(4)	47(3)	49(3)	52(3)	53(4)	55(3)	57(3)	58(3)	59(4)	61(4)	62(4)	63(4)	64(3)	65(4)	66(4)	70(1)	85(2)	86(2)	87(2)	88(2)	2566(3)	2569(2)	3811(4)
* Dehli	113 35	28 39	33 55		SW																								V	A		V			G
* Dhaka Bengale	130 00	27 00																													A				
* Dimashq	70 00	33 15	30 31		SE		A			V			R	A				A	A	A	V	V		G	-	A			A	A			V	A	
* Dinawar	83 00	35 00	22 00																	A															
Farawah	90 00	39 00	32 00																	A															
* Firuzabad	87 30	28 10			SW																								A	V				A	G
Firuzkuh	54 45	35 40	11 12		SW																			G											
* Fowman	84 40	37 20	24 16		SW																A					A									
* Ganjah	83 00	41 20	15 49		SW		A					A	R	A														V							G
* Garh-Manikpur?	118 10	29 49																												A					
* Gerfadman	85 30	34 14	38 41		SW		V	V	V	A		V	R		A			A		V	A	V	V			A									G
Ghazni	104 20	33 35																												A				A	
* Ghazyab	99 00	36 44	51 35																	A															
Giul	106 40	19 00																												A					
* Golkonda	114 20	28 04																												A	V			V	
Gopamau	116 33	26 45																												A					
* Gorgan	89 30	37 55	41 20		SW															A							V								
* Gwalior	114 00	26 29																												A	V			A	
* Ḥalab	72 10	35 50	18 29		SE		A	A		A			R	V	A			A	V	V	V			G		A		V	A	A		A		A	
* Ḥalvan	102 55	34 33	24 00																		A	V							V						
* Hamadan	83 00	35 10	22 16	324	SW	V	A	A	A	A	V	V	R		A	A	V	V		V	A	V	V	G	A	A	V					A	A	A	G
Hansi	112 25	29 45																												A					
Ḥiṣn Manṣur	72 24	34 00																																A	
* Herat	94 20	34 30	54 00	322	SW	V	V				A	V	R			V	V		V	V	V	V		G	V	A	V	A	V	A	V	A	V	A	G
* Ḥimṣ	70 15	34 00	29 00		SE																A	V													
* Hormoz	92 00	25 00	74 30		SW	V	A						R							A									A	A	A	A		V	
* Irwan	89 15	38 30	36 20		SW				A			A									V	A				A									G

* Işfahan	86 40	32 25	40 29	354	SW	V	V	V	A	V	A	A	R	V	V	V	V	V	V	A	V	V	V	G	A	V	A	A	V	V	A	A	A	V	G
Iskandaria	61 57	30 18																											A						
* Jaj wahu Shash	109 00	42 30																														A			
Jamkut	177 00	5 00																																A	
Jazirat a Suly?	150 00	1 00																																A	
Jazirat a Danakeli?	88 30	17 00																																A	
* Jazirat Bani Kawan?	88 00	21 00																																A	
Jazirat Mahadhaj?	88 30	25 00																																A	
Jazirat Salan?	71 00	14 00																																A	
Jiddah	76 00	21 00																												A				A	
* Juniper	119 06	26 36																												A				A	
Ka ᶜbah Musharafa	77	21 40		354													A																		
* Kabul	104 40	34 26	69 35		SW					V	V				V	V		V	V		A	V	V							V	V			V	
Kabulistan	104 40	35 00	32 25																										A						
Kajur	87 10	36 25																		A															
Kalpi	116 45	26 55																												A					
* Kannauj	115 50	26 35																												A					
* Kashan	86 00	34 00	34 31	323	SW	V	A	A	A	A	A	A	R	A	A	A	A	A	A	A	A	A	A	G	V	A	A	A	A	A		A	V	A	G
* Kashgar	106 30	45 00	58 36																	A									A	V		A		V	
* Kashmir	108 00	35 00	71 09		SW		V						R							V					A					A	A	A	A	A	
* Kazerun	87 00	29 15	11 17		SW		A	A	A	A	V		R		A			V	V	V	V	V				V									
* Kerej	84 45	34 00																											A						
Kermanshah	83 00	34 30	23 18		SW															A				G											G
* Kerman	92 30	29 50	62 51		SW	V	V				V		R			V			A		A	A		G		A	V			V				V	G
Kernal	23 55	32 40	14 16		SW																			G											G
Khabir	100 00	8 48																																A	
* Kharma Habash	65 00	21 30																											A						
* Khenpayet	109 20	26 20																												A	V			A	
Khohanabad	103 00	29 00																																A	
Khotan	107 00	42 00																		A										A		A		A	
* Khujand	85 35	41 55																		A										V		A			
Khuwai	79 40	37 40																																A	

Table I.A.—Continued

Place name	Longitude	Latitude	Azimuth	Distance	Direction	CCA No. (parameters) 15(3)	25(4)	31(4)	37(4)	39(4)	40(3)	42(3)	44(4)	47(3)	49(3)	52(3)	53(4)	55(3)	57(3)	58(3)	59(4)	61(4)	62(4)	63(4)	64(3)	65(4)	66(4)	70(1)	85(2)	86(2)	87(2)	88(2)	2566(3)	2569(2)	3811(4)
* Khuwana	106 33	38 24														A																			
Khuzem ez-Gidon	85 10	37 00																														A			
* Khwarizm	92 30	42 40	40 57													A																			
Kojur wa Kader	86 50	36 25																														A			
* Kufa	79 30	31 30	12 31	223	SW		A			A			R			A	A	A		A				G	A	V	V		A	V	A		V	A	G
* Kufa wa Najaf	79 30	31 30	12 30		SW																	A													
* Kul wa Jalali	114 19	28 04																												A					
* Lahawar	89 20	31 15	73 26		SW								R																						
* Lahijan	84 45	36 10	29 20		SW				A		A	V									V	V				A									
* Laḥsa	83 30	24 00	69 30		SW		A			A			R		A	V		A	A	A	A	A		G		A									
* Lahore	109 20	31 50	48 26		SW		V														A	A	A					A	A	A	A	A		A	
Lucknow	114 13	26 30																												A					
* Madayin	72 03	33 32	12 30		SE																	A												V	
* Mahdiyyah	42 00	32 30																											A						
Maleṭia	71 00	37 00																											A						
Mandu	111 25	22 15																												A					
* Maragheh	82 00	37 20	16 17		SW		A	V	A	V		V	R	V	A	A		A		A	A	A		G		A	V		V	A				A	G
Marand	80 45	37 50																											A						
Mardin	74 00	37 15																											A						
* Marw	97 00	37 40	12 30		SW					A	V	A			A	V		V	A			V		G											G
* Marw al-Roudh	90 00	36 30	52 30																	A															
* Mashhad-Turshiz	92 30	36 00	46 25											A																					
* Mazinan	90 30	37 00	32 14																	A															
Mecca	77 10	21 40	00 00		00	A	A		A	A		A	R	A	A			A	A	A	A	A		G		A	A	A	A					A	G
* Mecca Mu ʿaẓẓa-mah	77 10	21 40																												A	A	A			
* Medina	75 20	25 00	37 10		SE		A		A	A	A	V	R	V	A			A	A	V	A	A		G		A		A	A						G

Medina D.	75 20	25 00																														A			
Medina Musharafa	75 20	25 00																																A	
Medina Tayyiba	75 20	25 00																												A	A				
* Meshhad	92 30	37 00	45 06		SW		A		A		A	A	R			A				A										V					
Meshhad Muqaddas	92 30	36 00																						G										A	G
* Mimand	101 55	33 20																												A		A			
* Mişr	63 20	30 20	18 38		SE		A		V	A			R		A			A	A	A	A	A		G		A		A	A		A	A		A	
* Mosul	77 00	34 30	17 12		SW		V	A		V			R		A			A		V	V							V							
* Multan	107 35	29 40	78 59							V	V		R					V							V				V	A	A	A	A	V	
Nahawand	83 15	34 20	24 20																	A				G					A						G
* Nahrvara	102 30	22 00																														A			
* Najwaseru			12 34													A																			
* Nakhijewan	81 15	38 40	12 15		SW		A	A		V			R		V			A		A	V	A				A		A						A	G
Nasfin	86 30	33 00																											A						
Niruz	114 00	25 20																												A					
* Nishapur	92 30	36 21	46 25	342	SW	V	A		A	A	A	A	R	A	A	A	A	V	A	V		A	A	G		A	A						V		G
Nowshehr	78 20	38 10																						G										A	G
* Paniphateh	113 20	28 52																												A				V	
Patna	120 45	26 40																													A				
* Penjahir ez-Kabul	84 40	35 00																														A			
Pershawer	85 55	31 00																												A				A	
* Qandahar	107 40	33 00	75 05	449	SW		V			V	A	A	R		V	V	V	V		A	V	V			V	A	V	V	V	A	A	A	V	A	G
* Qanuj	114 50	26 20																														V		A	
Qaşr Shirin	81 40	33 45																																A	
* Qayen	93 20	33 40	54 01		SW		V			V	A		R	A		A		V	A	V		A				A							V		
* Qayrawan	41 00	31 40																											A	A				V	
* Qayşariya	66 30	32 30																											A						
* Qazvin	85 00	36 00	27 34	353	SW	V	A	A	A	A	A	V	R	A	A	A	V	V		V	V	V	V	G	A	A	V	A	V	A		A	A	V	G
* Qolzum	64 00	29 30																											A						
* Qom	85 40	34 45	31 14	335	SW	V	A	V	V	A	V	A	R		A	V	V	V		A	A	A	A	G		V	V		V				V	A	G
* Qostantin	59 50	45 00																											A						
Qurṭubah	48 26	35 00																											A						

TABLE I.A.—Continued

Place name	Longitude	Latitude	Azimuth	Distance	Direction	CCA No. (parameters)																													
						15(3)	25(4)	31(4)	37(4)	39(4)	40(3)	42(3)	44(4)	47(3)	49(3)	52(3)	53(4)	55(3)	57(3)	58(3)	59(4)	61(4)	62(4)	63(4)	64(3)	65(4)	66(4)	70(1)	85(2)	86(2)	87(2)	88(2)	2566(3)	2569(2)	3811(4)
Qusṭanṭiniyya		45 00																										A							
Raḥbeh	74 35	34 10																											A						
Ramhormoz	85 15	31 00																																A	
Ramlah	66 50	32 10																											A						
Raqqah	73 15	36 00																											A						
Ras al-Ain	74 00	36 50																																A	
* Rayy	86 20	35 00	37 26	335	SW	V			V		A	V		V		V	V				A	V	V			V			A					A	
* Rumieh	85 27	41 50																											A						
* Sabzawar	91 30	36 00	44 13		SW		V		V	V	V		R	V	A	V		V		V		A	V	G	V	A			A	V	V		V		G
Salamas	79 15	36 40																											A					A	
* Samarqand	99 16	39 37	14 14		SW	V				V					A	V		V		V	V	V	V		-			V	V	A	V	A	V	V	G
Sambhal	115 20	28 18																												A					
Samir	85 40	32 15																																A	
* Samirah	79 00	34 00	7 56								A																							V	
* Ṣana ͨa	77 00	14 30	1 15		NE		A	A		A			R		A			V		A				G		A			A						
* Sarakhs	94 30	37 00	42 12		SW											V				A				G											G
* Sarandib	130 00	10 00	70 12																	A										A		A		A	
* Sari	88 00	37 00	32 14	456	SW				V		A	A				V	V			V				G									V		G
* Sariyeh	88 00	37 00																														A			
* Sarmin	71 07	35 15																											A						
* Sarouj	72 40	34 50																												A				A	
* Sawah	85 00	35 00	29 18			V						V				V									A								A		
* Semnan	88 00	36 00	36 17	382	SW		A	A	A	A	A	A	R	A	A	A	A	V	A	A	A	V	V	G	V	A	V		V				V		G
* Shahjahanabad	113 35	28 39																													A				
* Shahrazur	81 20	36 03	24 00		SW																A	V												V	
Sham		33 00																										A							
* Shamakhi	84 30	40 50	20 09													A												V							

* Shapur	86 55	30 00																											A					A	
* Shiraz	88 00	29 36	53 20	279	SW	V	V	V	V	V	V	V	R	V	V	V	V	V	V	V	V	V		G	V	V	V	A	A	A	A	A	A	A	G
* Shirwan	84 30	40 50	20 09	323	SW		V		A			V	R	A			V		A		A	A				A	V								
* Shustar	84 30	31 30	35 24	322	SW		A	A	A	A	A	A	R		A	A	V	V	A	A	A	A			V	A			A				V		G
* Sialkut	109 00	33 00																												A				A	
* Sijilmasah	37 00	31 30																											A						
Sinjar	76 00	36 00																											A						
Sistan	97 00	32 30	63 18		SW																					A									
* Solṭaniyeh	83 30	36 36	26 40			A																												V	
* Sowiet	106 00	57 00																														A			
* Suhraward	102 20	32 30																											A						
* Sultan Kot	115 00	28 30																												A					
* Sumyat	72 35	40 00																											A						
Sunam	112 25	30 30																												A				A	
* Surra Man Raʾa	79 00	34 00	7 16		SW		A		A	A			R					V	V	A	V	V	A	G		V			A						G
Susan al-Aqsa	15 30	32 00																											A						
* Tabariyyah	68 00	32 00																											A						
* Ṭabas	92 00	33 00	52 10													V				A															
* Ṭabas Kylek	92 00	33 00	53 02																														A		
* Tabriz	82 00	38 00	15 40	374	SW	V	V	A	V	A	A	A	R	A	A	A	A	A	A	A	A	A		G	A	A	A	A	A	A	A	V	A	A	G
* Tahert Ulya	35 30	29 00																											A						
* Ṭaliqan	85 45	36 10	29 33		SW		V	V	A	V			R	V	V			A		V		V	V			V			A						
Tarablus al-Maghrib	45 00	32 00																											A						
Tarablus Sham	69 40	34 00																											A						
Tarsus	68 40	36 42																											A						
Tayif	77 30	21 20																												A				A	
* Tehran	86 20	35 00	10 23		SW															A				G			V								G
* Thanah	102 07	25 10																											A						
* Thaniser	112 33	30 10																												A				V	
* Tibbat	110 00	40 00																												A				V	
* Tiflis	83 00	43 00	14 41		SW		A		A				R			V																			

TABLE I.A.—Continued

	Place name	Longitude	Latitude	Azimuth	Distance	Direction	15(3)	25(4)	31(4)	37(4)	39(4)	40(3)	42(3)	44(4)	47(3)	49(3)	52(3)	53(4)	55(3)	57(3)	58(3)	59(4)	61(4)	62(4)	63(4)	64(3)	65(4)	66(4)	70(1)	85(2)	86(2)	87(2)	88(2)	2566(3)	2569(2)	3811(4)
							CCA No. (parameters)																													
*	Tun	92 30	34 30	50 20		SW		V			A	A		R		A	A		A	A	V		A	A			A			A		V		V		
*	Turshiz	92 00	35 00	48 51	411	SW											A	V			A		V	V			A									G
*	Ṭus	92 30	37 00	45 06	451	SW	V				A					A		V	A	A		A	V	V		V	A	V		V		V		V		
	Ujain	110 50	23 30																												A					
	Wain	100 50	23 20																																A	
*	Wasit	81 30	32 20	20 14																V															A	
*	Yazd	89 00	32 00	48 29	359	SW	V	V	V	V	V	A		R	V	V	V	V	V	V	V	A	A	A	G	V	V	V		V	A	V	A	V	A	G
	Zabid	74 20	14 10																											A						
	Zafar ez al-Milan	77 00	14 30																														A			
*	Zanjan	83 00	36 30																																A	

NOTES TO TABLE I.A

Refer to Literature Cited for bibliographic details.

Abarquh: Modern Abarqu. Le Strange (1966) lists Abarḳuh.

ᶜAden: No. 2569 has longitude 77 00.

Adhoun: No. 55 has Qibla azimuth 11 13; No. 52 has 51 18 for this same parameter. The characters forming the place name can also be read *Uzen*. Yaqut (volume 1, page 167) locates this named place in the area of modern Rayy and Teheran.

Agra: Nos. 39 and 55 have longitude 84 00 and latitude 27 33.

Aḥmadabad: No. 87 has longitude 88 00.

Ajmireh: Modern Ajmer. No. 87 has latitude 24 00. No. 85 has latitude 25 00. No. 86 has latitude 26 26.

Akbarabad: This city is not in the *Times Atlas*, but see Bartholomew (1893) map 27 Db with coordinates close to 27° in latitude. No. 87 has longitude 114 00.

Akhlat: Nallino (no. 164) has this city as Khilaṭ, longitude 78 00 and latitude 39 20. (Nallino, no. 164 refers to an entry in the table in *Al-Battani sive Albatenii Opus Astronomicum*, volume 2, pages 33–54.)

Allahabad: Bartholomew (1893) (map 28, Bc) has latitude around 25 50.

Al-lan: Nallino (volume 2, no. 172) mentions this city.

Al-Rum: See also Arḍ Rum and Arz al-Rum below; see Nallino (1899–1907, volume 2, pages 41, 46).

Amid: This city is not in the *Times Atlas*; but see Nallino (1899-1907, volume 2, page 41) for a mention.

Amol: No. 42 has longitude 87 20, latitude 36 15 and azimuth 35 00. No. 52 has latitude 36 15 and azimuth 34 57. No. 58 has latitude 36 15 and azimuth 36 45. No. 70 has latitude 38 00.

Amol Qaṣabat T.: The word *Qaṣabat* is usually used to refer to a large city; i.e., a capital or administrative city of a region, or simply a large city in a given region (Yaqut, volume 7, page 95). The Qaṣabat named here is the same as the city of Amol listed above in the table. See Nallino (1899–1907, volume 2, page 53), where he spells this city *Amul*.

ᶜAmuriyyah: Nallino (volume 2, page 44) mentions this city. Morley (in Gunther, no. 76) has the same coordinates. This city is not on a modern map (no. 76 refers to Morley's list of cities in the gazetteer of the Shah's astrolabe which appears on pages 24–26 in Gunther's edition of Morley's description. The parameters on this astrolabe are rather certain because the inscribed numbers are written out in words.)

Ardabil: The following variant readings appear in the collection: longitude 82 00 (No. 88); latitude 33 00 (No. 39), and latitude 38 17 (on Nos. 59 and 61); and azimuths 17 33 (on Nos. 25, 31, and 52), and 57 13 (on No. 64).

Arḍ Rum: See note for Al-Rūm above. Arz and Arḍ sound alike in Persian.

Asku Qaṣabat J.: This could be the Medieval city of

Abskun (according to Yaqut) or Abaskun (according to Le Strange). It does not appear on modern maps.

ᶜAsqalan: Nallino (volume 2, page 38) gives longitude 65 00, latitude 31 50. The city may be Ascalon, Israel.

Asterabad: The following variant readings appear in the collection: longitudes 81 35 (on No. 58) and 89 30 (on Nos. 66 and 85); latitude 36 05 (on no. 66) and azimuths 18 48 (on Nos. 25, 39, and 49), 38 47 (on entry Nos. 47 and 2566) and 37 48 (on entry no. 58).

Awadh: The Arabic spelling of modern Oudh reflects the aspirated final *d* in the native pronunciation. For coordinates, see Bartholomew (map 28, Cb). Forrest's map has Oude northeast of Lucknow.

Bab al-Abwab: This city is modern Derbent (Darband). See Nallino (volume 1, page 172) for mention. No. 88 has latitude 43 00.

Babulghar: This city may be Babol Sar in the area of the Bulgar river delta.

Badakhshan: Variant readings for parameters include: longitude 84 24 (Nos. 39, 49, and 55); latitudes 37 20 (No. 39) and 34 10 (No. 52); azimuths 44 09 (No. 49) and 64 19 (No. 55).

Badhaghis: Morley (No. 89) has these coordinates. See Abulfeda (volume 2:2, page 194) where he quotes the book *Aṭwāl* and gives coordinates for this city (longitude 83 30 and latitude 35 20).

Baghdad: Variant readings include: longitudes 82 00 (on Nos. 42, 44, 52, 57, 59, 65, and 2569), 80 30 (on No. 85) and 100 00 (on No. 66); latitude 34 00 (on No. 61); and azimuths 13 00 (on No. 15), 32 45 (on No. 52), 12 85 (on No. 49), 12 15 (on No. 25) and 7 16 (on No. 61).

Bait al-Maqdis: Variant readings include azimuths 45 43 (on No. 58) 45 16 (on No. 25) and 47 (on Nos. 59 and 61). This city is modern Jerusalem.

Bakar: Bartholomew (map 26, Bb) has Bakar in Afghanistan with latitude ca. 26° and a longitude equivalent to 105° east. Thus, longitude 85 00 may be a misreading.

Bakouyeh: The astrolabe could be read as Bakewir. See Yaqut (1861–1906, volume 1, page 45) and Barbier de Meynard (1861, page 78) for Bakouyeh, a city in the district of Derbent.

Balkh: Variant readings include: latitudes 36 00 (on No. 86) and 36 11 (on No. 2569); and azimuth 65 36 (on No. 25).

Banaras: Entry No. 88 has longitude 117 20.

Bardaᶜ: Modern Barda in Azerbaydzham. No. 59 has latitude 36 27.

Barfurush: Morley (No. 26) has these coordinates. Nos. 58 and 65 have longitude 87 50. Nos. 61 and 62 have azimuth 34 14.

Baṣra: Variant readings include: longitude 14 00 (on No. 53) and 44 30 (on No. 31); latitude 30 11 (on No. 86); azimuths 37 19 (on Nos. 25, 37, 39, 49, 55, 57, 61, 65, and 66), 36 00 (on Nos. 52 and 53), 36 05 (on No. 2566), 37 11 (on No. 58), and 17 19 (on No. 31).

Basṭam: Variant readings include latitude 36 20 (on Nos. 39, 49, 52, and 59) and azimuths 36 50 (on No. 2566), 18 13 (on Nos. 39, 49, and 55), 38 13 (on Nos. 59, 61, and 62), and 38 53 (on No. 65), 39 33 (on Nos. 40 and 47), and 39 53 (on No. 37).

Bijapur: Bartholomew (1959, map 34, Ba) has latitude ca. 17 00 and longitude near 75 00. No. 2569 has longitude 104 20 and latitude 17 40.

Biyar: See LeStrange (1966) for a mention of this city.

Broach: The astrolabe may be read Buruj; see al-Idrisi (1960, page 81).

Budaun: The astrolabe may be read Badawin for Budaun near modern Dehli.

Bukhara: Variant readings include: longitude 96 30 (on No. 15); latitudes 39 20 (on No. 15) and 34 20 (on No. 70); and azimuths 47 34 (on No. 15), 45 08 (on No. 39), 49 38 (on No. 49), and 49 37 (on No. 2566).

Bulghar: For the region and city known as Bulghar, see Yaqut (volume 2, pages 272–274) and Abulfeda (1848–1883, volume 2:1, pages 324–325). The name was given to the land of the Slavs north of the Caspian Sea around the Volga River.

Burhanpur: Nos. 86 and 2569 have longitude 103 00 and latitude 20 30.

Daibul: 2569 has longitude 81 40 and latitude 38 00. Nallino (No. 189) lists Daibul with longitude 100 00 and latitude 25 20. No. 88 appears to equate Daibul with the city of Tibbat. The two cities have different geographic coordinates, however.

Damavand: See Kushyar in Lelewel (volume 1, pages 182, 183) for this city as Damavend.

Damghan: Variant readings include: longitudes 18 15 (on Nos. 42 and 49), 88 15 (on Nos. 25, 31, 40, 47, 55, and 57), and 108 55 (No. 58); latitude 36 41 (on No. 62); azimuths 28 00 (on Nos. 25, 39, and 49), 36 20 (on No. 62), 38 00 (on Nos. 31 and 55), and 38 15 (on Nos. 42, 59, 61, and 65).

Daulatabad: This is the Indian city Daulatabad. Variant readings include longitude 111 00 and latitude 20 30 (both on entry Nos. 86 and 2569).

Dehli: This is modern Dehli. The spelling on the astrolabes usually includes the aspiration before the *l*. No. 85 has longitude 114 48 and latitude 28 47. No. 88 has longitude 103 35 and latitude 28 20.

Dhaka Bengale: The maker of the astrolabe which includes this place name has apparently conflated the longitude of Dacca in Bengal with the latitude of Dhaka in Bihar, India.

Dimashq: Variant readings include: latitudes 13 55 (on No. 39), 13 15 (on No. 61), and 33 25 (on No. 59) and azimuths 12 45 (on No. 61), 29 06 (on No. 2566) and 42 45 (on No. 59).

Dinawar: This place name does not appear in a modern atlas; it is, however, listed by Morley (1856) (No. 57).

Firuzabad: No. 86 has latitude 28 00.

Fowman: Morley (No. 28) transcribes this city name as Fuman.

Ganjah: Morley (No. 48) has these coordinates; entry No. 70 has latitude 40 40.

Garh-Manikpur?: This is a difficult reading. The two cities apparently named are in the vicinity of modern Ahmadpur with longitude near 81 00 and latitude near 25 00.

Gerfadman: This city is not on a modern map. Yaqut (volume 3, page 73) has a city by the name of Garbadgan, between Hamadan and Iṣfahan, which would fit these coordinates. Variant readings on instruments in the collection include: longitude 84 30 (on Nos. 37 and 42); latitude 34 15 (on Nos. 58 and 62); and azimuths 18 41 (on Nos. 58 and 62), 33 41 (on No. 25), and 38 00 (on Nos. 31, 42, and 61).

Ghazyab: Probably Ghaznayn, a variant spelling of Ghazni, or a different city in the same region. See Le Strange (page 348) and Yaqut (volume 6, page 289) for Ghaznayn as a different city from Gazni.

Golkonda: Nundo Lal Dey (pages 84 and 234) has Kala-Kunda as a city around 7 miles from modern Hyderabad. Variant readings include longitudes 114 19 (on No. 2569) and 114 39 (on No. 87) and latitude 18 04 (on No. 87).

Gorgan: No. 66 has longitude 94 00, latitude 36 50, and azimuth 52 45.

Gwalior: No. 87 has longitude 115 00.

Ḥalab: This is modern Aleppo. Variant readings include: latitude 35 06 (on Nos. 58 and 70) and azimuths 33 29 (on No. 57), 36 00 (on No. 59), 38 26 (on No. 47), and 70 31(?) (on No. 58).

Ḥalvan: Variant readings include: longitudes 102 15 (on No. 85) and 82 15 (on No. 61) and latitudes 36 03 (on No. 61) and 34 00 (on No. 85).

Hamadan: Variant readings (probably due to different sources) include: longitudes 84 00 (on No. 15), 85 00 (on Nos. 61 and 62), and 88 00 (on Nos. 55 and 66); latitudes 36 00 (on Nos. 61 and 62), and 30 10 (on No. 66); and azimuths 22 17 (on No. 40), 27 26 (on Nos. 61 and 62), 22 36 (on No. 42), 24 16 (on Nos. 53 and 58), and 25 30 (on No. 15).

Herat: Variant readings include: longitudes 93 30 (on Nos. 52 and 53) 94 33 (on No. 87), and 94 13 (on No. 85); latitudes 34 35 (on Nos. 64 and 2566) and 37 30 (on No. 15); and azimuths 14 08 (on Nos. 25, 42, and 57), 14 35 (on No. 66), 51 38 (on No. 53), 53 11 (on No. 15), 53 54 (on No. 2566), 54 05 (on No. 58), and 54 08 (on Nos. 59 and 61).

Ḥims: No. 61 has latitude 34 03.

Hormoz: Variant readings include: longitude 92 20 (on No. 2569) and azimuth 73 41 (on No. 15).

Irwan: This city which seems to be on the southeast side of the Caspian Sea, cannot be identified. No. 59 has azimuth 37 20.

Iṣfahan: Variant readings include: longitudes 87 40 (on Nos. 85 and 86) and 86 00 (on Nos. 52 and 53); latitudes 32 24 (on No. 49), 32 35 (on No. 2569), and 34 25 (on Nos. 59, 61, and 62); and azimuths 30 23 (on No. 15), 40 25 (on No. 59), 40 18 (on Nos. 25, 39, 49, 55, and 65), 40 28 (on Nos. 31 and 57), and 40 45 (on No. 47).

Jaj wahu Shash: This name appears to be an attempt to render the pronunciation of a letter *J* which is lateralized to sound like *SH.* Hence the astrolabist has both Jaj and Shash. See al-Biruni, Nallino (No. 80), Suhrab (No. 534) and Khwarizmi (No. 1585) for possible mentions.

Jazirat Bani Kawan?: The term *jazīrat* means "island."

Juniper: This city is sometimes spelled Jaipur, a name of many cities and one district in India in the vicinity of this city.

Kabul: The city with this name listed by Morley (1856) (No. 64) has longitude 104 40, latitude 34 07, and azimuth 69 57. Variant readings on instruments in the collection include: longitudes 84 24 (on No. 52), 54 40 (on No. 61), 84 40 (on Nos. 39, 40, 49, 55, 62, 87, and 2569); latitudes 34 16 (on No. 57), 34 20 (on No. 52), 34 30 (on Nos. 86, 87, and 2569) and 34 36 (on No. 40); and azimuths 69 30 (on No. 55), 64 34 (on No. 62) and 17 09 (on No. 52).

Kannauj: Arab sources traditionally write this city's name as Ginnuj. See Idrisi (page 159 and index) for an example. This city also may be identified with Yaqut's Qattuj.

Kashan: The few variant readings include: longitude 86 40 (on No. 15) and azimuths 34 33 (on Nos. 64 and 2566) and 36 08 (on No. 15).

Kashgar: Both Nos. 86 and 2569 have latitude 44 00.

Kashmir: Variant readings include longitude 88 00 (on No. 25), latitude 31 00 (on No. 25) and azimuths 68 40 (on No. 58) and 75 20 (on No. 25).

Kazerun: Variant readings include: latitude 29 45 (on No. 55) and azimuths 11 07 (on No. 58), 51 17 (on Nos. 57, 59, and 61), and 51 57 (on Nos. 40 and 65).

Kerej: See al-Biruni's *Qānūn* (page 568) for a reference to Kerej Abu Dalf.

Kerman: Variant readings include: longitudes 91 30 (on Nos. 86 and 2569), 91 40 (on No. 66) and 92 33 (on No. 40); latitudes 30 00 (on No. 66) and 30 05 (on Nos. 15, 86, and 2569); and azimuths 60 00 (on No. 66), 62 11 (on No. 25) and 63 00 (on Nos. 15 and 52).

Kharma Habash: See al-Biruni (*Qānūn*, page 549), Khwarizmi (No. 75, page 8) and Suhrab (No. 61, page 16) for possible mentions.

Khenpayet: This is the modern city of Cambay, Bombay, India. See al-Biruni (*Qānūn*, page 552) and Idrisi (page 86) for possible mentions. No. 87 has latitude 22 20.

Khujand: This is the city of Khujandah in Le Strange (1966, map IX). No. 86 has longitude 100 35.

Khuwana: Jacques de Morgan (1894) mentions a certain Khouna as a "village du delta du Kizil-Ouzen" in the district of Jilan. It could be the same as the city named here.

Khwarizm: This is definitely the region of Khwarizm, birthplace of Khwarizmi, al-Biruni, and others. Its capital is modern Khiva in Uzbekistan, USSR.

Kufa: Variant readings include: longitude 79 10 (No. 86) and azimuths 11 59 (No. 2566), 12 35 (No. 65), and 37 25 (No. 66).

Kufa wa Najaf: Modern al-Kufah and an-Najaf in Iraq which are very close to each other. An-Najaf is a sacred city for Shi^{c}ites, being the site of the grave of ^{c}Ali, the fourth caliph.

Kul wa Jalali: These are the two cities of Koil, modern Aligarh and Jalai in Uttar Pradesh, India.

Lahawar: The Medieval spelling of modern Lahore is Lahawar. See, for example, al-Idrisi (1960, pages 66 and 90).

Lahijan: Variant readings include: longitude 84 00 (Nos. 42, 59, and 61) and azimuth 29 40 (No. 42).

Laḥsa: This is the city Aḥsa$^{\supset}$ in Bahrain mentioned by Yaqut (volume 1, page 137), built by the Qarmatian Abu Ṭahir al-Ḥasan Ben Abi Sa^{c}id al-Jannani. See Abulfeda (1848–1883, volume 2:1, page 135) for the spelling Laḥsa as a vulgar form of al-$^{\supset}$Aḥsa$^{\supset}$ *Al-Aṭwal*, as quoted by Abulfeda (*ibid*), gives the coordinates longitude 73 00 and latitude 22 00. No. 52 has latitude 34 00. If longitude 83 00 is interpreted as an error, the reference could be Lhasa, Tibet, with longitude 103 00.

Lahore: Morley (No. 66) has 78 26 as the azimuth of Lahore. No. 25 has this azimuth and latitude 31 15.

Madayin: No. 2569 has longitude 72 00 and latitude 33 10. Al-Biruni (*Qānūn*, page 558) mentions al-mada$^{\supset}$in as being Tabsun.

Mahdiyyah: Lelewel (volume 1, page 139) has Mahadia reported at latitude 32 30 by Nasir al-Din al-Tusi and others.

Maragheh: Variant readings include: longitude 92 00 (on No. 66); latitudes 36 20 (on No. 66) and 37 13 (on No. 85); and azimuths 17 17 (on No. 47), 36 17 (on No. 31), and 56 57 (on Nos. 39 and 42).

Marw: This is modern Mary in Yurkemaniya, USSR. Variant readings include: longitude 107 00 (on No. 52) and azimuths 57 30 (on Nos. 40 and 61) and 52 30 (on No. 55).

Marw al-Roudh: This is a different city from Marw. See Lelewel (volume 1, page xlj) where he has Mervalroud with longitude 90 00, latitude 39 00. Marw is mentioned as another city in the fifth climate.

Mashhad-Turshiz: See Meshhad and Turshiz below.

Mazinan: This city could be modern Kalateh-ye Mazinan.

Mecca Mu^{c}aẓẓamah: Mecca and Medina are often mentioned with honorific names such as *mubārakah* (blessed), and *mu^{c}aẓẓamah* (glorified).

Medina: Variant readings include azimuths 23 00 (on No. 58), 27 10 (on No. 42) and 27 27 (on No. 47).

Meshhad: No. 86 has latitude 36 00.

Mimand: Al-Biruni (*Qānūn*, page 561) has longitude 93 40 and latitude 33 20.

Miṣr: This is modern Egypt. Variant readings include: azimuth 58 38 (on No. 37).

Mosul: Variant readings include: latitude 36 30 (on No. 70) and azimuths 4 12 (on No. 58), 6 54 (on No. 59), and 7 12 (on Nos. 25 and 39).

Multan: Variant readings include: longitudes 87 35 (on Nos. 39, 55, and 64), 106 35 (on No. 85) and 107 25 (on No. 2569); latitude 39 40 (on No. 64); and azimuth 80 48 (on Nos. 39, 40, and 55).

Nahrvara: This must be modern Patan. See al-Idrisi (1960, page 9).

Najwaseru: This reading is quite uncertain; the place name is inscribed in the center of the gazetteer with only the azimuth of the Qibla given.

Nakhijewan: Variant readings include: latitude 18 40 (on Nos. 39 and 49) and azimuth 12 14 (on No. 59).

Nishapur: Variant readings include: latitude 36 00 (on No. 55), and azimuths 45 00 (on No. 15) 46 13 (on No. 55), 46 26 (on No. 2566) and 46 35 (on No. 58).

Paniphateh: This is modern Panipat. Entry No. 2569 has latitude 28 50.

Penjahir ez-Kabul: For Penjahir, see al-Biruni (*Qānūn*, page 574) with coordinates longitude 94 20 and latitude 35 00.

Qandahar: There are two cities called Kandahar: one in Afghanistan, latitude 31 36; and one in India, latitude 18 54. Hence one can expect the coordinates given for this city to be confused. Variant readings include: longitudes 84 40 (on Nos. 39, 49, and 55), 87 40 (on Nos. 59 and 66), 106 40 (on No. 85); latitudes 18 00 (on Nos. 39 and 49), 23 00 (on No. 25), 33 40 (on Nos. 59 and 61), 33 45 (on No. 70), and 38 00 (on No. 55); and azimuths 74 00 (on Nos. 52 and 53), 74 31 (on Nos. 49 and 55), 74 59 (on Nos. 64 and 2566), 75 31 (on Nos. 39 and 61), and 42 00 (on No. 66).

Qanuj: No. 88 has *Qanuj dar malik Hind*, longitude 115 50 and latitude 26 36.

Qayen: This city's name is also spelled *Qain* or *Qayin*. Variant readings include: latitude 13 40 (on No. 39) and azimuths 14 36 (on No. 25), 52 01 (on No. 58), 15 01 (on Nos. 39 and 55), and 54 04 (on No. 2566).

Qayrawan: Al-Biruni (*Qānūn*, page 555) has longitude 31 00 and latitude 31 40. Entry No. 2569 has latitude 31 00.

Qayṣariya: See Nallino (1899–1907, No. 110) and al-Biruni (*Qānūn*, page 557) for mention.

Qazvin: Variant readings include: longitude 87 00 (on No. 53); latitudes 36 15 (on No. 58), 36 41 (on No. 62), 36 45 (on No. 2569), and 36 55 (on Nos. 66 and 85); and azimuths 25 34 (on No. 55), 27 26 (on Nos. 59, 61, and 62), 27 30 (on No. 15), 27 36 (on No. 66), and 27 37 (on No. 42).

Qolzum: This is the name of the Red Sea. For mentions of Qolzum, see Khwarizmi (1926, No. 160) and Suhrab (1929). See also Yaqut (1861–1906, volume 7, pages 145–147) for the name of the sea in which Pharoah drowned.

Qom: Variant readings include: longitudes 86 40 (on No. 15), and 87 40 (on No. 52); latitudes 34 40 (on No. 53), 35 00 (on No. 66) and 35 45 (on No. 85); and azimuths 31 54 (on Nos. 31, 37, 40, 53, and 65), 31 55 (on Nos. 66 and 2566), 32 14 (on No. 15), and 34 31 (on No. 55).

Qostantin: This is modern Istanbul. Al-Biruni (*Qānūn*, page 577) has Qustantiniya. See also Nallino (pages 33, 44, 212, and 217) for coordinates.

Rayy: This name refers to an area close to modern Shah ᶜAbdul-ᶜAẓim, modern Shahr Rey, south of Teheran. See Jacques de Morgan, (1894, page 392); Nallino (1899–1907, no. 172) and Yaqut (volume 4, pages 355f). Variant readings include: longitudes 16 20 (on No. 42) and 87 20 (on No. 47); latitude 35 41 (on No. 62); and azimuths 31 33 (on No. 15), 36 22 (on No. 62), and 36 26 (on Nos. 37, 47, 52, 53, 61, and 65).

Rumieh: For comments on this city, see Nallino (page 44). Also see Khwarizmi and al-Biruni (*Qānūn*, page 574) for coordinates.

Sabzawar: Variant readings include: latitudes 36 05 (on Nos. 37, 40, 47, 58, 64, 87, and 2566), 36 10 (on No. 86), and 36 21 (on No. 62) and azimuths 41 13 (on No. 55), 44 12 (on Nos. 25, 37, and 52), 41 13 (on No. 39), 44 12 (on No. 47), 44 46 (on Nos. 64 and 2566), 44 52 (on No. 40), and 46 25 (on No. 62).

Samarqand: Variant readings include: longitudes 98 00 (on No. 15), 99 34 (on No. 62), 99 36 (on Nos. 39, 52, 55, 58, and 59), and 99 56 (on Nos. 87 and 2569); latitudes 39 36 (on No. 55), 39 37 (on No. 58), and 40 00 (on Nos. 15 and 70); and azimuths 12 14 (on No. 62), 24 00 (on No. 59), 49 00 (on No. 15), 52 14 (on No. 58), 52 33 (on No. 2566), 52 54 (on No. 52), and 54 54 (on Nos. 85 and 61).

Samirah: This city is modern Samarra, which is the same as Surra Man Raᵓa below. No. 2569 has longitude 79 15 and latitude 34 15.

Ṣanaᶜa: No. 55 has latitude 34 30 and azimuth 1 55.

Sarakhs: No. 52 has azimuth 11 14.

Sarandib: See Lelewel (1852–1857, volume 5, page 74) for longitude 125 00, latitude 10 00. The reference is to modern Ceylon.

Sari: Variant readings include: longitude 83 00 (on Nos. 52 and 53), and azimuths 22 14 (on No. 53), 32 10 (on No. 37), 32 54 (on No. 2566), and 34 25 (on No. 58). This place name appears twice on No. 3811.

Sariyeh: This is a variant spelling of Sari.

Sarmin: Abulfeda (volume 2:2, page 42) quotes *Aṭwāl*, longitude 61 50 and latitude 31 15; Yaqut (volume 5, page 75) also gives coordinates.

Sarouj: Abulfeda (volume 2:2, page 52) spells this city's name as Saroug and quotes *Aṭwāl*, with longitude 62 40 and latitude 36 50 and *Qānūn* with longitude 62 15 and latitude 37 40. There is a discrepancy between the Hyderabad edition of al-Biruni's *Qānūn* and the edition quoted by Abulfeda.

Sawah: Variant readings include: latitude 35 40 and azimuth 29 10 (on No. 15), latitude 36 00 and azimuth 39 36 (on No. 42) and latitude 34 00 and azimuth 29 36 (on No. 52).

Semnan: Variant readings include: longitudes 88 41 (on No. 62), and 83 00 (on No. 85); latitudes 36 41 (on No. 62); and azimuths 34 35 (on No. 64), 34 38 (on No. 2566), 36 20 (on Nos. 61 and 62), 37 17 (on No. 55) and 36 37 (on No. 66).

Shahjahanabad: This is the modern city of Jahanabad in Uttar Pradesh, India. Shahjahan was one of the Mogul Emperors of India in the late seventeenth century (Lane-Poole, pages 322ff). The city Khohanabad, above, may be a mistake for this city.

Shahrazur: Variant readings include: longitudes 80 20 (on No. 2569) and 83 20 (on No. 61) and latitude 35 30 (on No. 2569).

Shamakhi: No. 70 has latitude 40 45.

Shapur: This is known to be an ancient site in Iran, close to Kazerun.

Shiraz: Variant readings include: longitude 108 00 (on No. 64); latitudes 29 00 (on Nos. 25, 39, 49, 53, 55, and 65) and 29 30 (on No. 15); and azimuths 13 18 (on Nos. 31 and 37), 23 28 (on Nos. 39, 55, 59, 61, and 65), 23 38 (on No. 40), 33 18 (on No. 42), 33 20 (on No. 52), 33 30 (on No. 53), 33 38 (on No. 25), 43 18 (on No. 47), 51 22 (on No. 15), 53 18 (on No. 58), 53 28 (on No. 57) and 53 38 (on No. 66).

Shirwan: Variant readings include: longitudes 81 30 (on No. 66) and 91 30 (on Nos. 25, 42, and 53); latitudes 36 00 (on Nos. 25, 53, and 66) and 36 05 (on No. 42); and azimuths 44 13 (on No. 25), 36 17 (on No. 53) and 44 14 (on No. 66). The two sets of parameters suggest that two distinct Shirwans are identified in the gazetteers. In fact, No. 42 lists both. These two Shirwans undoubtedly correspond to the two modern cities of Shirvan in Iran.

Shustar: Variant readings include longitude 34 30 (on No. 53) and azimuths 35 29 (on Nos. 64 and 2566) and 36 24 (on No. 55).

Sialkut: See Bartholomew (1959, map 25, Aa) for Sialkut; al-Biruni (*Qānūn*, page 562) has longitude 99 00 and latitude 33 00.

Sijilmasah: Al-Biruni (*Qānūn*, page 554) has longitude 18 45 and latitude 31 30.

Solṭaniyeh: No. 2569 has longitude 85 00 and latitude 36 30.

Sowiet: This is a reference to a whole country. The coordinates given are in the modern Omsk region of the USSR.

Suhraward: Barbier de Meynard (pages 329, 330) comments on the history of this city. Yaqut (volume 5, page 185) and Le Strange (page 223) locate this city close to Sultaniyyeh near Zanjan.

Sultan Kot: This city appears to be located in the vicinity of modern Moradabad, India.

Sumyat: This is probably the Sumaysat of Medieval writers. Nallino (No. 148) has longitude 72 00 and latitude 37 50.

Surra Man Raᵓa: This is modern Samarraᵓ. Yaqut (volume 5, page 75) gives this city's history. Variant readings include: longitude 79 30 (on No. 55) and azimuths 7 36 (on Nos. 59, 61, and 65) and 7 56 (on Nos. 55 and 57).

Tabariyyah: This is modern Tiberias.

Ṭabas: Entry No. 52 has azimuth 12 15.

Ṭabas Kylek: This city is the same as Tabas. Kylek could be the name of the district.

Tabriz: Variant readings include: longitude 81 15 (on No. 88); latitude 38 45 (on No. 88); and azimuths 15 00 (on No. 25), 15 30 (on No. 15) and 15 47 (on No. 37).

Tahert Ulya: This city may be the Tahart mentioned by Shems al-Din (Lelewel, 1852–1857, volume 1, page 177) with coordinates longitude 33 20 and latitude 34 00. Al-Biruni (*Qānūn*, page 564) lists two cities called Tahert: Tahert al^c^Ulya with longitude 20 00 and latitude 33 50, and Tahert al-Sufla with longitude 19 50 and latitude 34 55.

Ṭaliqan: Variant readings include: longitudes 85 00 (on No. 47), 85 31 (on No. 62) and 85 05 (on No. 61); latitude 36 20 (on Nos. 39, 61, and 62); and azimuths 21 30 (on No. 58), 29 10 (on Nos. 31, 62, and 65), 29 13 (on No. 49), 29 20 (on No. 61), and 29 13 (on Nos. 25 and 39).

Tehran: No. 66 has longitude 85 40, latitude 34 45 and azimuth 37 26.

Thanah: Modern Thano near Hyderabad, called Thano Bula Khan in Pakistan, with modern longitude 67 51 and latitude 25 23.

Thaniser: No. 2569 has longitude 112 00.

Tibbat: No. 2569 has longitude 100 00.

Tiflis: No. 52 has azimuth 14 11.

Tun: Variant readings include: longitude 52 10 (on No. 58); latitude 32 30 (on No. 87); and azimuths 10 20 (on No. 58), 50 24 (on No. 2566), and 55 20 (on No. 25).

Turshiz: Barbier de Meynard (1861, pages 135 and 390) lists this city under "Tourschisch." Now the city is called Kashmar. See Morley (1856, No. 32) for coordinates. Variant readings include: longitude 92 41 (on No. 62); latitude 34 00 (on Nos. 61 and 62); and azimuth 48 11 (on No. 53).

Ṭus: Variant readings include: longitudes 84 30 (on No. 66) and 94 30 (on No. 87); latitude 36 00 (on Nos. 15 and 85); and azimuths 40 00 (on No. 62), 40 06 (on No. 53), 45 00 (on No. 61), 45 09 (on Nos. 64 and 2566), 45 43 (on No. 15), and 45 46 (on No. 66).

Wasit: No. 57 has azimuth 20 54.

Yazd: Variant readings include: longitude 109 00 (on No. 85); latitudes 31 33 (on Nos. 15 and 87) and 32 30 (on No. 66); and azimuths 43 28 (on No. 66), 47 17 (on No. 15), 48 27 (on Nos. 47, 52, 53, 64, and 2566), 48 28 (on Nos. 25, 31, 37, 39, 55, 57, and 65), 48 40 (on No. 58), and 88 18 (on No. 49).

Zanjan: No. 2569 lists this place name twice, once with longitude 83 40.

TABLE I.B.—List of names and geographical parameters on No. 44

Place name	Longitude	Latitude	Azimuth	Place name	Longitude	Latitude	Azimuth
Agra	114	26	17	Mecca	77	22	0
Amol	88	36	35	Medina	75	25	37
Ardabil	82	38	17	Meshhad	92	37	15
Asterabad	90	37	39	Miṣr	63	30	19
Baghdad	82	33	13	Mosul	77	35	17
Bait al-Maqdis	67	32	46	Multan	87	30	81
Balkh	81	37	13	Nakhijewan	82	39	12
Baṣra	84	30	37	Nishapur	93	36	46
Damghan	83	36	38	Qandahar	88	73 ?	32
Dimashq	70	33	32	Qayen	93	34	55
Ganjah	83	41	16	Qazvin	85	36	10
Gerfadman	87	34	39	Qom	86	35	32
Ḥalab	72	36	18	Sabzawar	91	36	44
Hamadan	83	35	22	Ṣana^c^a	77	14	5
Herat	94	34	34	Semnan	88	36	36
Hormoz	92	25	74	Shiraz	88	29	13
Iṣfahan	87	32	40	Shirwan	91	36	44
Kashan	86	34	35	Shustar	85	32	35
Kashmir	88	31	75	Surra Man Ra^ɔ^a	79	34	7
Kazerun	87	29	11	Tabriz	82	38	16
Kerman	93	30	42	Ṭaliqan	86	36	10
Kufa	80	32	12	Tiflis	83	83 ?	15
Lahawar	89	31	73	Tun	92	34	50
Laḥsa	84	24	70	Yazd	89	32	48
Maragheh	82	37	16				

TABLE I.C.—List of names and geographical parameters on No. 3811 (five place names could not be read and have not been included in the table)

Place name	Longi-tude	Lati-tude	Azi-muth	Direc-tion	Place name	Longi-tude	Lati-tude	Azi-muth	Direc-tion
Ardabil	48 18	38 10	25 09	SW	Marw	62 10	37 30	56 10	SW
Asterabad	54 32	36 31	43 31	SW	Mecca	40 10	21 33	00 00	00
Badkuba	29 55	40 20	26 17	SW	Medina	39 55	25 00	?7 22	SE
Baghdad	44 25	33 20	28 42	SW	Meshhad Muqaddas	59 50	36 20	14 32	SW
Bahihan	50 30	30 34	48 12	SW	Nahawand	44 53	34 05	30 25	SW
Barfurush	52 45	36 30	39 39	SW	Nakhijewan	48 08	36 45	28 04	SW
Basṭam	55 00	36 25	44 59	SW	Nishapur	58 46	36 08	53 07	SW
Bukhara	64 29	39 45	55 41	SW	Nowshehr	50 56	29 01	55 17	SW
Damghan	54 38	36 07	44 46	SW	Qandahar	66 20	32 35	? 22	SW
Dehli	49 00	30 20	33 55	SW	Qazvin	49 55	36 10	34 46	SW
Firuzabad	52 45	35 40	41 14	SW	Qom	40 56	34 30	38 59	SW
Ganjah	46 22	40 30	14 15	SW	Sabzawar	57 22	36 12	50 17	SW
Gerfadman	44 55	32 00	20 ?	SW	Samarqand	66 50	39 56	23 03	SW
Hamadan	48 00	34 52	29 22	SW	Sarakhs	61 00	36 30	56 10	SW
Herat	62 20	34 45	61 39	SW	Sari	53 05	36 29	40 28	SW
Irwan	44 35	40 10	20	SW	Semnan	53 32	35 33	43 25	SW
Iṣfahan	51 50	32 40	45 08	SW	Shiraz	58 40	29 37	57 15	SW
Kashan	51 28	33 59	41 10	SW	Shustar	49 00	32 00	39 03	SW
Kermanshah	47 40	34 23	25 40	SW	Surra Man Ra᾽a	44 00	34 00	? 8	SW
Kerman	56 30	29 50	60 11	SW	Tabriz	46 25	38 00	19 51	SW
Kernal	23 55	32 40	14 16	SW	Tehran	51 20	35 40	37 30	SW
Kufa	45 00	31 30	15 ?	SW	Turshiz	58 50	39 08	54 51	SW
Maragheh	46 12	37 08	20 17	SW	Yazd	56 00	32 10	57 14	SW

Appendix II

Star Names

The names of stars inscribed on the ᶜ*ankabūts* or retes of the astrolabes described in the catalog entries are grouped here in four annotated tables. Table II.A lists all stars inscribed using Arabic characters. Table II.B lists the stars named on the rete inscribed with Hebrew characters. Table II.C lists stars named on the astrolabe inscribed with Sanskrit characters. Table II.D groups the stars found on retes inscribed with Latin characters. The following symbolism has been adopted in all four tables:

- ? = Problematic reading or identification.
- A = Name appears on instruments as listed in the table.
- V = Name on instruments is a close variant of the name listed. The reader should refer to the note associated with the star name for information about the nature of the variation.
- B = Name inscribed on back of ᶜ*ankabūt* or rete.
- * = Annotation appears in list following table.

Standard astronomical abbreviations have been used in the "star" column to identify the stars named.

In Table II.A the conventions for transcribing Arabic characters adopted in the text and catalog are adhered to in this table. Column 2 of the table contains references to the two primary sources of information leading to the identification of the named stars. Entries in this column beginning with "A" refer to the numbered *Astrolabesterne* discussed by P. Kunitzsch in *Arabische Sternnamen in Europa* (pages 59–96). Entries in the same column beginning with "K" refer to one of the stars numbered and discussed in the main portion of Kunitzsch's *Sternnamen* text. Three other references proved helpful in solving problems of identification. They are: R.H. Allen, *Star Names, Their Lore and Meaning*; Aṣ-Ṣufi, *Ṣuwaru ᵓl-Kawakib*; and Ulugh Beg, *Catalogue of Stars*, translated by E.B. Knobel.

Bernard Goldstein's article, "The Hebrew Astrolabe in the Adler Planetarium," proved to be the most helpful source of information about the Hebrew star names in Table II.B. The identifications tabulated there are tentative. The reader is referred to a forthcoming study of this astrolabe (CCA No. 2572) by Professor Goldstein and George Saliba. The table adheres to the conventions for transliteration adopted by Goldstein in "The Hebrew Astrolabe."

The information in Table II.C was kindly provided by Professor David Pingree of Brown University, who examined photographs of the rete of No. 4000. The reader is referred to Professor Pingree's article, "History of Mathematical Astronomy in India," especially pages 626–628, for further discussion of Sanskrit star names.

The references cited above for Table II.A also proved helpful in preparing Table II.D. The entries in column 2 in this table refer to P. Kunitzsch's *Arabische Sternnamen*, as explained above. A numerical reference to the brightness of a given star is inscribed following its name on two entries, Nos. 221 and 2007.

TABLE II.A.—Star names inscribed with Arabic characters

Star name	Reference	Star	CCA No.																																		
			4	15	25	31	37	39	40	42	44	47	49	52	53	54	55	57	58	59	61	62	63	64	65	66	70	88	144	2566	2567	2568	2569A	2569B	2571	3643	3811
* ᶜAbur	A23	α CMA																									A		V			A			A		
ᶜAyn al-Thaur	A18	α TAU			A	A	A	A	A	A	A	A	A	A	A	A	A			A	A	A		A	A		A	A		A	A		A				A
* ᶜAyyuq	A20	α AUR	V		A				A	A			A	A	A			A	A	A	A	A	A	A			A	A	V	A	A				A		A
ᶜUnq al-Ḥayyah	K196	α SER			A	A	A	A	A	A	A		A	A	A	A	A			A	A	A			A			A	A				A				A
ᶜUnq	K196	α SER	A																															A			
Aᶜzal	A39	α VIR		A							A													A					A	A		A			A	A	A
* Al-Dabaran	A18	α TAU	A	V															V				V			?			V			A			V	A	
Al-Dajajah	A56	α CYG															A																				
Al-Dhanab	A55	ε DEL																											A								
Al-Difdaᶜ	A6	β CET																																		A	
* Al-Dubb	A33	α UMA																														A					
Al-Fakkah	A45	α CBR	A	A																							A		A			A					
* Al-Fard	A29	α HYD												V	V	V											A										
* Al-Ghul	A14	β PER	A		V	V	V	V		V	V									V	V	V			V				A			V	A	V	V		
* Al-Ghumayṣa	A45	α CMI																											A			V			V		
* Al Ghurab	A36	γ COR																											A			A					
* Al-Hani al-Nahr	K59	τ ERI									A																										
* Al-Ḥawwa	A51	α OPH	A	A																			V			A			A			A			A		A
Al-Ḥayya	K196	α SER																														A			A		
* Al-Inaq	A38	ζ UMA																															A		A		
* Al-Jizah	?	?	?																																		
* Al-Kaff al-Jadhmaᵓ	A13	α CET									V	V																					A			A	
* Al-Khaḍib	A2	β CAS	A	A							V					A											A				A				V		
* Al-Maqbiḍ Yad al-Yusra	?	?																															?				
* Al-Minkab	A62	β PEG	V																						V				A								V
* Al-Minkab	A22	α ORI																											A			V			V		
* Al-Musalsalah	A10	γ AND																										A					A				

TABLE II.A.—Continued

Star name	Reference	Star	CCA No. 4	15	25	31	37	39	40	42	44	47	49	52	53	54	55	57	58	59	61	62	63	64	65	66	70	88	144	2566	2567	2568	2569A	2569B	2571	3643	3811
* Al-Naqar		β BOO																																		A	
* Al-Nasr	A54	α AQL		?																																	
Al-Naṭih	K96	β TAU																								A											
* Al-Qalb	A48	α SCO																											A								
* Al-Ramiḥ	A41	α BOO	A	A	V		V	V	V	V	V	A								V	V	V	V	V			A		A	V	V	A			A	A	A
* Al-Ra᾽s		α TRI		A																																	
* Al-Ridf	A56	α CYG	V				V	V	V	V	V		A						A	V	V	V	A	V	V		V		A	V	V	V			V	A	A
Al-Rijl	A28	μ UMA																											A								
Al-Rijl	A19	β ORI																											A								
Al-Rukbat	A9	α UMI																											A								
* Al-Ṣarfah	A35	β LEO													V									V			A	V		V					V		
Al-Shamiyyah	A25	α CMI										A											A				A										
* Al-Shaᶜra al-Shamiyyah	A25	α CMI	A											V			V		V									V					V				V
* Al-Shiraᶜ	?	?	A																																		
* Al-Simak al-Aᶜzal	A39	α VIR	A		V	V	V	V	V	V		V	V	V	V	V	V	V	V	V	V	V	V		V	V	V	V					V				
* Al-Ṭayir	A54	α AQL	A								V	A						A					V						A			A		V	A	A	
* Al-Waqiᶜ	A53	α LYR	A	A						V	V	A											V	V			V		A	V	A	V	V	V	V	A	
* Al-Yamaniyyah	A23	α CMA	A	V																				V						V	V					A	
Al-Zubanah	K4	α CAN																											A						A		
Baṭn	K73	δ ARI																											A								
Baṭn al-Ḥut	A7	β AND																										A					A				
Baṭn Qayṭus	A8	ζ CET																											A			A			A		
Dalfin	A55	ε DEL	A																													A					A
* Dhanab al-ᶜUqab		ζ AQL				A							A																								
Dhanab 2	A59	δ CAP																														A					
Dhanab al-Dajajah	A56	α CYG			A							A																					A				
Dhanab Dalfin	A55	ε DEL																													A						

Table II.A.—Continued

Star name	Reference	Star	CCA No.																																		
			4	15	25	31	37	39	40	42	44	47	49	52	53	54	55	57	58	59	61	62	63	64	65	66	70	88	144	2566	2567	2568	2569A	2569B	2571	3643	3811
Dhanab al-Ḥut	A55	ε DEL																										A									
* Dhanab al-Jadiy	A59	δ CAP	A	A		V					A												A					A					A		A		A
* Dhanab Janubi Qayṭus	A6	β CET			A																					V											
* Dhanab Qayṭus	A6	β CET		A			A	A	A		V		A		A					A	A	A			A			V				A	V		A		
* Dhanab Qayṭus	A4	ι CET	A							A																							V				
* Dhanab Qayṭus Janubi	A6	β CET															V										A										
Dhanab Qayṭus Shamali	A4	ι CET				A																															
Dhanab al-Ṭayir		ζ AQL																																		A	
Fakkah	A45	α CBR									A						A						A											A	A		
* Fam al-Faras	A58	ε PEG			A	A	A	A	A	A	V		A		A		A	A		A	A	A		A	A					A			A	V		A	A
Fam al-Ḥut	A61	α PSA																					A														
Fam al-Ka'ʾs	A32	α CRA																																	A		
* Fam Qayṭus	A13	γ CET		A			A	A	A	A	A		A							A			A					V					V				A
Faras	A62	β PEG																														A					
* Fard al-Shujaʿ	A29	α HYD		V	A		A	A	A	A	V	A	A				A	A		A	A	A		A	A			A		A			A				A
Fargh al-Muqaddam	A62	β PEG																																		A	
Jabhat Qayṭus	A13	α CET																									A										
* Janaḥ al-Ghurab	A36	γ COR	A		A		A	A	A	A	V	A	A		V		A			A	A	A			A		A	A					A				A
* Kaʿb	K130	γ AUR																											A								
* Kaʿb al-Faras		τ PEG																																	A		
Kaff	A2	β CAS													A																						
Kaffah Janubi	A43	α LIB				A																															
Kaff al-Kahḍib	A2	β CAS							A	A			A	A			A			A	A	A		A				A		A			A				A
* Liraʾs al-Ḥawwa	A51	α OPH																									A										
* Mankib		β AUR																																A			
* Marfiq	A15	α PER							A																												
* Marfiq Thurayya	A15	α PER																															A				

TABLE II.A.—Continued

Star name	Reference	Star	CCA No. 4	15	25	31	37	39	40	42	44	47	49	52	53	54	55	57	58	59	61	62	63	64	65	66	70	88	144	2566	2567	2568	2569A	2569B	2571	3643	3811
* Masafat al-Nahr	A17	γ ERI				V	V	V	V	V			A							V	V	V							?				A				
Matn Faras	A63	γ PEG														A	A																				
* Minkab al-Faras	A62	β PEG					A	V	A	A	V		A				A			A	A	A	A					A			A		A	V	V		
* Minkhar Shuja^c		σ HYD																															A				
* Minqar al-Dajajah	K14	β CYG				A									A									V		?		A		V			A				A
* Mirzam al-Shamaliyyah	K143	β CMI																					V													A	
* Muqaddam	A24	α GEM																					A				A										
* Muqaddam Qa^cidat	K35	ε VIR																		A											V						
* Nasr Ṭayir	A54	α AQL			A	A	A	A	A	A			A	A	A	A	V		A	A	A	A		A	A		A	A		A	A		A				A
Nasr Waqi^c	A53	α LYR			A	A	A	A	A				A	A	A	A	A			A	A	A			A			A					A				A
* Nathr Sahabi		ε CAN																										A									
* Nayyir Fakkah	A45	α CBR			A	A	A	A	A	V		V	A	V	V			A		V	V	V		V	A	A		A		V	V		A			V	A
* Nayyir Qa^2id	A40	η UMA															A																				
* Qadam al-Jawza^2	A19	β ORI																														A				A	
Qa^2id	A40	η UMA				A																													A		
Qa^cidat	A32	α CRA				A	A	A	A	A	A		A							A	A	A			A	A											
* Qa^cidat al-Batiyah	A32	α CRA										V																					A			A	A
* Qalb al-^cAqrab	A48	α SCO	A	A	A		A	A	A	A	V		A	A					A	A	A	A		A	A		A	A		A		A			A		A
* Qalb al-^2Asad	A30	α LEO	A	V	A					A	A	A	A	A	A		A		A	A			A	A		A	A	A		A					A		
* Qayṭus	A4	ι CET																								A	?										V
Qayṭus Janubi	A6	β CET																																			A
Ra^2s al-Ghul	A14	β PER												A					A									A								A	A
* Ra^2s al-Ḥawwa	A51	α OPH			A	A	A	A	A	A	V		A		A		A	A		A	A	A		A	A			A		A	A		A	V		A	
Ra^2s al-Jathi	A49	α HER																										A					A				
Ra^2s al-Muthallath	K94	α TRI																						A						A							
* Ridfah	A56	α CYG				?									A																						
* Rijl Dubb		μ UMA																																	A		
* Rijl al-Jawza^2	A19	β ORI	A																				V	A			V			A	A				A		

TABLE II.A.—Continued

Star name	Reference	Star	4	15	25	31	37	39	40	42	44	47	49	52	53	54	55	57	58	59	61	62	63	64	65	66	70	88	144	2566	2567	2568	2569A	2569B	2571	3643	3811
			CCA No.																																		
* Rijl al-Jawza᾿ al-Yumna		χ ORI				A																											A				
* Rijl al-Jawza᾿ al-Yusra	A19	β ORI				A								A														A					A				
Rijl al-Saratan	K54	β CAN																																		A	
* Rijl Yumna		χ ORI									A								V																		
* Rijl al-Yusra	A19	β ORI		V	A		A	V	A	A		A	A		A	A	A		A	A	A	A															A
* Sabiq al-᾿Awwal	K168	ζ OPH																															?			A	
* Ṣadr Qayṭus		γ CET					A	A	A	A			A							A	A	A			?								V				A
* Saif al-Shaı	?	?																																		?	
Saq		δ AQR				A																															
* Saq ᾿Ayman	A60	δ AQR					A	A	A	A			A			A	A			A	A	A			A	?											
* Saq ᾿Ayman Sakib	A60	δ AQR			A																																
Saq al-Dalw	A60	δ AQR																																		A	
* Saq Sakib al-Ma᾿	A60	δ AQR										A		?	A																		A				A
Shaᶜra Ghumayṣa᾿	A25	α CMI																													A						
* Shaᶜra Yamaniyyah	A23	α CMA			A	V	V	V	V			V	V	A	A	V	V	V	A	V	V	V	V		V			A					V				V
* Shami	A25	α CMI		V	A	A	A	A	A	A	A		A		V	A				A	A	A		V	A	A				V							
Shujaᶜ	A29	α HYD																					A						A			A			A		
* Simak Ramiḥ	A41	α BOO				A							A	A	A	A	V	A	A						V	A		A					A				
* Suhail al-Fard	A29	α HYD																																		A	
Surrat al-Faras	A1	α AND																						A						A			A				
Ṭaraf Safinah	A27	ρ PUP									A																						A				
* Wasat al-Batiyah		? CRA																																		A	
* Yad Dubb		? UMA																																	A		
* Yad Qayṭus		? CET													A																						
* Yad al-Jawza᾿	A22	α ORI										A		A	A								V	A						A	A		A				
Yad al-Jawza᾿ al-Yumna	A22	α ORI																									A	A									
* Yad al-Jawza᾿ al Yusra		γ ORI																									A						V				
* Yad Yumna	A22	α ORI	V	V	A		A	A	A	A	A		A							A	A	A			A												A

TABLE II.A.—Continued

Star name	Reference	Star	4	15	25	31	37	39	40	42	44	47	49	52	53	54	55	57	58	59	61	62	63	64	65	66	70	88	144	2566	2567	2568	2569A	2569B	2571	3643	3811
Yad Yusra		γ ORI									A																										A
Yamani	A23	α CMA								A	A															A											
* Ẓahr al-Dubb	A33	α UMA					A	A	A	A			A							A	A	A			A			?									A
* 3 al-Naᶜamat		? CET																																		A	
? al-Nahr	?	?																																			A
? qad Rukbat al-Dubb		α UMI	A																																		
? Qayṭus		? CET	A																																		
? al-Tinnin	A52	γ DRA																															A				
Blank																																A					
Dot																	A																				
Obliterated																														A							

NOTES TO TABLE II.A

ᶜAbur: Read *al-ᶜAbūr* on No. 144.
ᶜAyyuq: Read *al-ᶜAyyūq* on No. 4 and No. 144.
Al-Dabaran.: Read *al-Dabar* on No. 144; read *Dabarān* on Nos. 15, 58, 63, and 2571.
Al-Dubb: This name, appearing on No. 2568, apparently refers to the whole constellation of Ursa Major.
Al-Fard: Read *Fard* on Nos. 52, 53, and 54.
Al-Ghul: Read *Ghūl* on Nos. 25, 31, 37, 39, 42, 44, 59, 61, 62, 65, 2568, 2569B, and 2571.
Al-Ghumayṣa: Read *Ghumayṣā* on Nos. 2568 and 2571.
Al Ghurab: Identified with γ Corvis, but could refer to the entire constellation.
Al-Hani al-Nahr: Kunitzsch has *inḥināt an-Nahr.*
Al-Ḥawwa: Probably identical with *Raᵓs al-Ḥawwā.* Read *Ḥawwā* on No. 63.
Al-Inaq: See Allen, page 440, for identification.
Al-Jizah: Difficult reading; unidentifiable.
Al-Kaff al-Jadhmāᵓ: Read *Kaff al-Jadhmā* on Nos. 44 and 47.
Al-Khaḍib: Read *Khaḍīb* on Nos. 44 and 2571.
Al-Maqbiḍ Yad al-Yusra: Difficult reading; unidentifiable.
Al-Minkab: Read *Minkab* on entry Nos. 4, 65, and 3811.
Al-Minkab: Read *Minkab* on entry Nos. 2568 and 2571.
Al-Musalsalah: Kunitzsch (1959) has *rijl al-Musalsalah.*
Al-Naqar: See Allen, page 103, for identification.
Al-Nasr: Difficult reading.
Al-Qalb: On No. 144, this star name is in the position of *Qalb al-ᶜAqrab.*
Al-Ramiḥ: Read *Rāmiḥ* on Nos. 25, 37, 39, 40, 42, 44, 59, 61, 62, 63, 64, 2566, 2567.
Al-Raᵓs: This star appears to be identical with *Raᵓs al-Muthallath.*
Al-Ridf: Read *Ridf* on Nos. 4, 37, 39, 40, 42, 44, 59, 61, 62, 64, 65, 70, 2566, 2567, 2568, and 2571.
Al-Ṣarfah: Read *Ṣarfah* on Nos. 53, 64, 88, 2566, and 2571.
Al-Shaᶜra al-Shamiyyah: Read *Shaᶜra Shāmiyyah* on Nos. 52, 55, 58, 88, and 2569A; read *Shaᶜra Shāmī* on No. 3811.
Al-Shiraᶜ: Unidentifiable. The phrase means the "sail" and may refer to a part of Puppis.
Al-Simak al-Aᶜzal: Read *Simāk Aᶜzal* for all entries except No. 4, which reads *al-Simāk al-Aᶜzal*, and Nos. 65, 70, and 2569A, which read, *Simāk al-Aᶜzal.* The word A*ᶜzal* is repeated on entry No. 47.
Al-Ṭayir: Read *Ṭāyir* on Nos. 44, 63, and 2569B.
Al-Waqiᶜ: Read *Wāqiᶜ* on Nos. 42, 44, 63, 64, 70, 2566, 2568, 2569A and B, and 2571.
Al-Yamaniyyah: Read *Yamāniyyah* on Nos. 15, 64, 2566, and 2567.
Dhanab al-ᶜUqab: See Allen (1899, page 61) for identification.
Dhanab al-Jadiy: Read *Dhanab Jadiy* on No. 31.
Dhanab Janubi Qayṭus: Read *Dhanab Janūbī* on No. 66.

Dhanab Qayṭus: Read *Dhanab al-Qayṭus* on Nos. 44 and 88 and *Dhanab al-Qayṭus 3* on No. 2569A.

Dhanab Qayṭus: This pointer could refer to either ι or β Ceti on Nos. 4 and 42. A pointer marked *Dhanab Qayṭus 12* on No. 2569A may refer to λ Ceti.

Dhanab Qayṭus Janubi: Read *Dhanab al-Qayṭus Janūbī* on No. 55.

Fam al-Faras: Read *Fam Faras* on No. 44. Read *Fam* on No. 2569B.

Fam Qayṭus: Read *Fam al-Qayṭus* on Nos. 88 and 2569A.

Fard al-Shujaᶜ: Read *Fard* on No. 15 and *Fard Shujāᶜ* on No. 44.

Janaḥ al-Ghurab: Read *Janāḥ* on entry No. 53 and *Janāḥ Ghurāb* on entry No. 44.

Kaᶜb: See Kunitzsch (1959, page 180, note 2).

Kaᶜb al-Faras: This should probably be read as *Karab.* See Kunitzsch, *Untersuchungen zur Sternnomenklatur der Araber* (1961, No. 145).

Liraᵓs al-Ḥawwa: The maker probably intended *Raᵓs al-Ḥawwā.*

Mankib: See Allen (1899, page 89) for this identification.

Marfiq: See Kunitzsch (1959) main entry No. 121, for this identification. See also Allen, page 331.

Marfiq Thurayya: *Ibid.*

Masafat al-Nahr: The reading on No. 144 is problematic. Nos. 31, 37, 39, 40, 42, 59, 61, and 62 have *Masāfat.*

Minkab al-Faras: Read *Minkab Faras* on Nos. 39, 44, and 2571. No. 2569b has *Faras.*

Minkhar Shujaᶜ: See Allen (1899, page 250) for identification.

Minqar al-Dajajah: Read *Minkār* on Nos. 64 and 2566. The reading on No. 66 is problematic.

Mirzam al-Shamaliyyah: Read *Mirzam* on No. 63.

Muqaddam: See Allen (1899 page 231) for problematic identification.

Muqaddam Qaᶜidat: Read *Muqaddam* for No. 2567. This star is also known as *Mutaqaddim-li-l-Qaṭṭāf.*

Nasr Ṭayir: Read *Nasr al-Ṭāyir* on No. 55.

Nathr Sahabi: See Kunitzsch (1959, page 63, No. 10) for identification.

Nayyir Fakkah: Read *Nayyir al-Fakkah* on Nos. 42, 47, 52, 53, 59, 61, 62, 64, 2566, 2567, and 3643.

Nayyir Qaᵓid: Possibly a combination of *Qāᵓid* and *Nayyir Fakkah.*

Qadam al-Jawzaᵓ: *Qadam* is equivalent to *rijl.*

Qaᶜidat al-Batiyah: The word *al-Bāṭiyah* is repeated on No. 47.

Qalb al-ᶜAqrab: Read *Qalb ᶜAqrab* on No. 44.

Qalb al-ᵓAsad: Read *Qalb* on No. 15.

Qayṭus: On No. 3811, the word *Qayṭus* appears to be followed by the word *Shamālī*, thus linking this pointer with ι Ceti. The identification is problematic for No. 70.

Raᵓs al-Ḥawwa: Read *Raᵓs Ḥawwā* on No. 44; read *Raᵓs* on No. 2569B.

Ridfah: Problematic reading on No. 31.

Rijl Dubb: See Kunitzsch (1959, page 75, for identification.

Rijl al-Jawzaᵓ: No. 70 has *Rijl* on two separate pointers. One of these undoubtedly represents β Orionis; the identity of the second is problematic. No. 63 has *Rijl Jawzaᵓ*

Rijl al-Jawzaᵓ al-Yumna: See Allen (page 318) for identification.

Rijl Yumna: *Ibid.* Read *Rijl al-Yumnā* on No. 58.

Rijl al-Yusra: Read *Rijl* on No. 15; read *Rijl Yusrā* on No. 39.

Sabiq al-ᵓAwwal: The reading on No. 2569A is problematic.

Ṣadr Qayṭus: Read *Ṣadr al-Qayṭus* on No. 2569A. The reading on No. 65 is problematic.

Saif al-Shara: Doubtful reading; unidentifiable.

Saq ᵓAyman: Reading on No. 66 is problematic.

Saq ᵓAyman Sakib: Possibly a combination of *Sāq ᵓAyman* and *Sākib al-Māᵓ*, both references to the constellation Aquarius.

Saq Sakib al-Maᵓ: The reading on No. 52 is problematic.

Shaᶜra Yamaniyyah: Read *Shaᶜra Yamānī* on all entries except Nos. 25, 52, 53, 58, and 88.

Shami: Read *Shāmiyyah* on Nos. 15, 53, 64, and 2566.

Simak Ramiḥ: Read *Simāk al-Rāmiḥ* on Nos. 55 and 65.

Suhail al-Fard: See Allen (1899, page 249) for identification.

Wasat al-Batiyah: Identification is problematic.

Yad Dubb: *Ibid.*

Yad Qayṭus: *Ibid.*

Yad al-Jawzaᵓ: Read *Yad Jawzā* on No. 63.

Yad al-Jawzaᵓ al Yusra: Read *Yad al-Jawzāᵓ* on No. 2569A.

Yad Yumna: Read *Yad* on Nos. 4 and 15. See Kunitzsch (1959, pages 63, 64) for distinction between *Yad Yumnā* and *Yad Yusrā.*

Ẓahr al-Dubb: Reading on No. 88 is problematic.

3 al-Naᶜamat: This name appears to refer to a group of stars, possibly η and θ in Cetus.

TABLE II.B.—Star names inscribed with Hebrew characters on CCA No. 2572

Star Name	Reference	Star
Al-Aᶜzal	A39	α VIR
Dabaran	A18	α TAU
Fakka	A45	α CBR
Ha-Ramiḥ	A41	α BOO
Lev ha-ᶜAgrav	A48	α SCO
Lev ha-ᵓAryeh	A30	α LEO
Meᶜoff ef	A54	α AQU
Nof el	A53	α LYR
Regel	A19	β ORI
Zenev ha-Gedi	A59	δ CAP
Qayṭ us[?]*	?	CET
Ridf*	A56	α CYG

* These two star names are engraved on the back of this ᶜ*ankabūt*. There is a third, as yet undeciphered word or phrase inscribed on the back of the ecliptic band of this ᶜ*ankabūt*.

TABLE II.C.—Star names inscribed with Sanskrit characters on CCA No. 4000 (two star names, including one possibly referring to α Cygni, were undecipherable from the photograph)

Star Name	Star
Ardra	α ORI
Avijit	α LYR
Chitra	α VIR
Dhanuk	α OPH
Hasta	γ COR
Lubdhaka	α CMA
Magha	α LEO
Purvab	β PEG
Rohini	α TAU
Samudrapakshi	ι CET
Skavana	α AQU
Swati	α BOO

TABLE II.D.—Star names inscribed with Latin characters

Star Name	Reference	Star	CCA No.							
			186	204	221	262	304	2005	2006	2007
Agorab	A36	γ COR					A			
Al	A41	α BOO					A			
Alabor	A23	α CMA							A	
Alacrab	A48	α SCO							A	
Alchimech	A39	α VIR							A	
* Aldebaran	A18	α TAU					V		A	
Alfard	A29	α HYD							A	
Alfeta	A45	α CBO							A	
Alfra	A62	β PEG					A			
Algeber	A19	β ORI							A	
Algnib	A15	α PER							A	
Algol	A14	β PER	B							
* Algomeisa	A25	α CMI					V		A	
Alhaio	A20	α AUR					A			
Alhave	A51	α OPH					A			
Aliot	A28	ι UMA	B							
* Altaire	A54	α AQI					V		A	
Andromeda 3	A7	β AND				A				A
Aquila 2	A54	α AQI				A		A		A
Aramech	A41	α BOO							A	
* Arcturus 1	A41	α BOO				V				A
Arturus	A41	α BOO						A		
Audiens	A41	α BOO	A							
C Eq	A62	β PEG	A							
* Canis Maior 1	A23	α CMA		V	A	A	V	A		A
Canis Meridionalis	A23	α CMA	A							
* Canis Minor 1	A25	α CMI		A	V			V		A
Cap Med 2	A14	β PER								A
Capra	A20	α AUG				A				
Caput Dragonis	A52	γ DRA	A							
* Caput Herculis	A49	α HER		V				A		
Caput Ophiuchi 3	A51	α OPH								A
Caput Serpen	A51	α OPH		A		A				
Cast	A24	α						A		
* Cauda Capricor 3	A59	δ CAP						V		A

TABLE II.D.—Continued

Star Name	Reference	Star	CCA No.							
			186	204	221	262	304	2005	2006	2007
Cauda Ceti 3	A6	β CET	A	A	A	A		A		A
Cauda Delphin 3	A55	ϵ DEL								A
* Cauda Leonis	A35	β LEO				A				V
* Cauda Signi 2	A56	α CYG		V						A
Caudaurse	A33	α UMA	A							
Collarium Canis	A23	α CMA	A							
* Cor Leonis 1	A30	α LEO	A	V	V	A		A	A	A
Corona	A45	α CBO				A				
Cor Scorpii 2	A48	α SCO						A		A
Corvus	A36	γ COR				A			A	
* Crus Aquarii		α AQU			V			A		
Crus Pegasi 2	A62	β PEG								A
Delphin	A55	ϵ DEL				A			A	
Denebalgida	A59								A	
* Dex Humerus Orio 1	A22	α ORI		V	V					A
Dex Lat Per 2	A15	α PER								A
* Dor Ur Maio 2	A33	α UMA		V	A					
Extre Cau Ur Ma 2	A40	η UMA								A
Fundus Vasis 4	A32	α CRA			A					
* Gallina	A56	α CYG	B					V		
Gorgo	A14	β PER				A				
* Hemerus Equi	A63	α PEG	V		V	V			A	
Hidra	A29	α HYD				A				
Hircus 1	A20	α AUR	A		A			A		A
Holor	A56	α CYG				A				
Idra	A29	α HYD						A		
Lanceator 1	A41	α BOO		A	A					
Lancis Libre	A43	α LIB		A						
Lira 1	A53	α LIR				A		A		A
* Lucida Hidrae 2	A29	α HYD		V	V					A
Markeb	A27	ρ PUP							A	
Menchar	A13	α CET							A	
Mirach		β UMA							B	
Mus Pega 3	A58	ϵ PEG			A					
Mychar		ϵ BOO							B	

Table II.D.—Continued

Star Name	Reference		CCA No.							
			186	204	221	262	304	2005	2006	2007
Naris Ceti 3	A8	ζ CET			A	A				
* Oculus Tauri 1	A18	α TAU	V	V	V	V		A		A
Os Ceti	A13	α CET	A							
Palma Ophiuchi 3	A47	δ OPH								A
Patera	A32	α CRA				A				
Pentecaitos	A8	ζ CET							A	
Pec Cassiop	A5	α CAS						A		
Pegasus	A63	α PEG				A		A		
Perses	A15	α PER						A		
* Pes Orion	A19	β ORI		A	V			V		
Pleiades	A16	η TAU						A		
Prima Caude Ur Ma 2	A37	ϵ UMA								A
Procion	A25	α CMI				A				
Rasaden	A52	γ DRA							A	
Raz Alawe	A51	α OPH							A	
* Rigil		χ ORI					V		A	
Rostrum Corvi 3		α COR								A
Septentri	A45	α CBO		A						
* Sini Hu Bootis 3	A42	γ BOO	V		A					
* Sinister Pes Orion 1	A19	β ORI				A				A
* Spica Virginis 1	A39	α VIR	V	V	V	A		A		A
Tibia Aquar	A60	δ AQU						A		
Umbi Andro 3	A7	β AND			A					
* Ursa Maior	A40	η UMA				V		A		
Venter Ceti 3	A8	ζ CET	A	A	A	A				A
Vertebrum Aquarii	A60	δ AQU	A							
* Vultur Cadens 1	A53	α LYR	A	V	A					
* Vultur Cadens	?	?						A		
Vultur Volans	A54	α AQU	A							
* Wega	A53	α LYR					V		A	
Yed	A47	δ OPH				A				

Notes to Table II.D

Aldebaran: Read *Aldeb'an* on No. 304.
Algomeisa: Read *Algomesa* on No. 304.
Altaire: Read *Altair* on No. 304.
Arcturus 1: Read *Arctur'* on No. 262.
Canis Maior 1: Read *C. Maior* on No. 204; read *Caniz* on No. 304.
Canis Minor 1: Read *Canis Min* on No. 221; read *Can^s Min 1* on No. 2005.
Caput Herculis: Read *C. Herculis* on No. 204.
Cauda Capricor 3: Read *Cauda Capricorni* on No. 2005.
Cauda Leonis: Read *Cauda ♌ 2* on No. 2007.
Cauda Signi 2: Read *Cauda Signis* in No. 204.
Cor Leonis 1: Read *Cor ♌ 1* on No. 221; read *C*Leo* on No. 204.
Crus Aquarii: Read *Crus ♒* on No. 221.
Dex Humerus Orio 1: Read *Dex Hu Orion 1* on No. 221 read *Hu Orionis* on No. 204.
Dor Ur Maio 2: Read *Dorson Urse* on No. 204.
Gallina: Read *Gall^a* on No. 2005.
Hemerus Equi: Read *Hume: Equi* on No. 262; read *Hu E Ma* on No. 221; read *H Eq* on No. 186.
Lucida Hidrae 2: Read *Lucida Hy 2* on No. 221; read *Lucida Hydre* on No. 204.
Oculus Tauri 1: Read *Oculus* on No. 262 and *Oculus 1* on No. 221; read *O Tauri* on No. 204; read *Oculus Taurus* on No. 186.
Pes Orion: Read *Pes Sinis Orio 1* on No. 221. Read *Pes Orionis* on No. 2005.
Rigil: Read *Regel* on No. 304.
Sini Hu Bootis 3: The rete of No. 186 incorporates an unscribed anthropomorphic figure, which appears to point to this star.
Sinister Pes Orion 1: Read *Si: Pes Orionis* on No. 262.
Spica Virginis 1: Read *Spica* on No. 186; read *Spica ♍ 1* on No. 221 read *Spica Virgini* on No. 204.
Ursa Maior: Read *Ursa* on No. 262.
Vultur Cadens 1: Read *V Cadens* on No. 204.
Vultur Cadens: Entry No. 2005 has a star pointer marked *Lira* in addition to this one marked *Vultur Cadens*.
Wega: Read *Vega* on No. 304.

Appendix III

The Principle of Stereographic Projection

The design of the astrolabe is based on a simple model of the universe which assumes that the sun moves on the surface of a vast celestial sphere centered on the earth. The principle of stereographic projection is used to represent the apparent circular path of the sun (the ecliptic) on the planar surface that constitutes the astrolabe rete.

Stereographic projection, as developed by Hipparchus and applied by Claudius Ptolemy in his "Planisphaerium" (see his *Opera*), involves projecting figures on a sphere representing the celestial sphere from one of its poles onto a plane parallel to its equator (see Figure 129). The important characteristic of this projection is its pres-

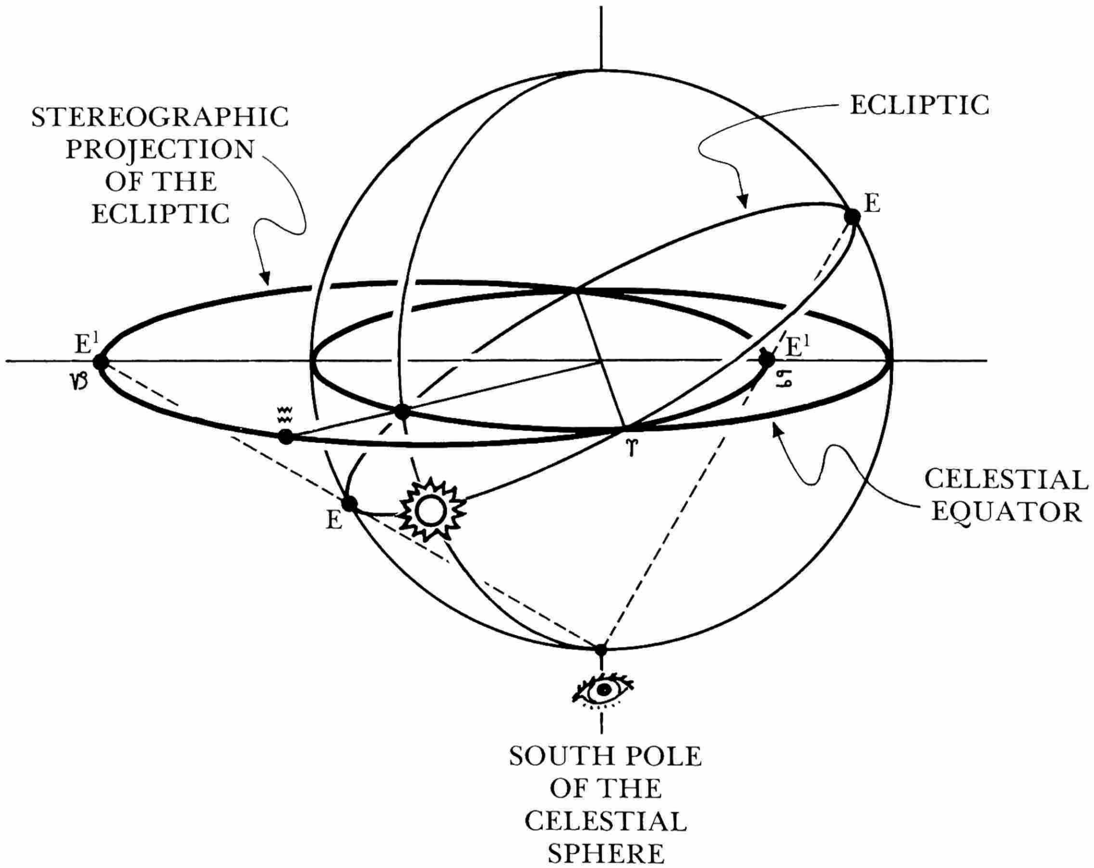


FIGURE 129.—The principle of stereographic projection.

ervation of circles and angles. The stereographic projection of a circle on the sphere is a circle in the plane of projection.

One way of judging the skill of an astrolabist is to assess the precision with which he utilizes stereographic projection to produce the various representational lines and circles on the parts of his instrument. For example, an evaluation of the precision of an astrolabe can result from examination of the ecliptic circle, which forms part of its rete. In his account of the utilization of stereographic projection, Ptolemy shows that the zodiacal divisions of the ecliptic may be accurately positioned on the stereographic projection of the ecliptic by first locating the points of intersection of the celestial equator with great circles passing through the poles of the celestial sphere and the zodiacal boundary points. Points thus located on the projection of the celestial equator (the "right ascensions" of the zodiacal boundary points) connected to the center of the projection of the celestial equator define a radius that intersects the stereographic projection of the ecliptic at points identical with the stereographic projections of the zodiacal boundary points. Figure 130 shows the correct angular separation of zodiacal boundary points as located by Ptolemy's method.

Emmanuel Poulle describes five alternative

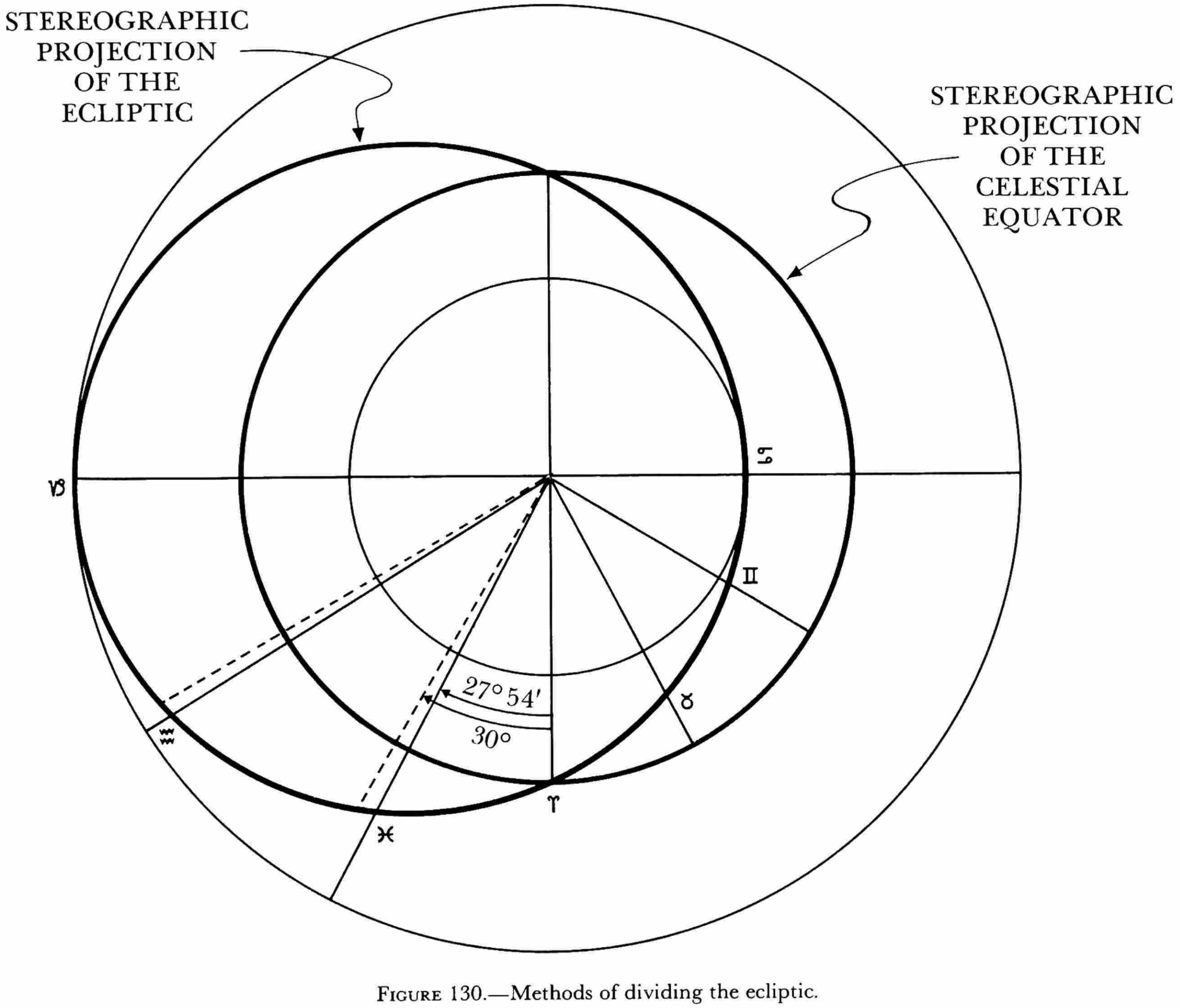


FIGURE 130.—Methods of dividing the ecliptic.

methods of dividing the ecliptic band in his "La fabrication des astrolabes au Moyen Age." The least accurate of these, preferred by Hermann Contractus and many astrolabists, entails approximating the location of the zodiacal boundary points by considering them to be identical with the points of intersection between the stereographic projection of the ecliptic and radii connecting the center of the projection of the celestial equator with points defining 30° arcs on that projection. Figure 130 shows that this method, however lacking in its theoretical base, can result in a very close approximation of the position of the zodiacal boundaries on an astrolabe rete.

Notes

1. The modifier, planispheric, limits this discussion to instruments that include in their design a plane projection of the celestial sphere. The most frequently employed means of projection is described in Appendix III.

2. Henri Michel's *Traité de l'Astrolabe*, published in Paris in 1947 and now available in a 1976 edition, remains the best modern contribution to this genre. W. Hartner's "The Principle and Use of the Astrolabe," published in *Oriens-Occidens* in 1968 is an excellent treatment of the subject in English. The recent appearance of several make-it-yourself astrolabe kits suggests the existence of an enduring interest in the instrument's structure and application.

3. Theon's work on the astrolabe is available only indirectly in the works of later authors. Otto Neugebauer has traced the transmission process and reconstructed the original Theon in an article on "The Early History of the Astrolabe."

4. The Arabic (first) and Latin (second) terms are given for each of the astrolabe's major components. Conventional transliteration has been used throughout.

5. In this discussion, the term "European" is used exclusively to refer to astrolabes inscribed with Latin alphabetic characters. Astrolabes made in Spain and inscribed with Arabic characters are identified as maghribi.

6. The history of the sea or mariner's astrolabe is ably presented by David Waters in *Agrupamento de Estudos de Cartografia Antiga, Seccao de Coimbra.* There is one Spanish example dating from the mid-sixteenth century in the collections of the National Museum of American History.

7. The seasonal (or "temporal" or "unequal") hours are those utilized by the ancient Greeks and Romans to divide each day's light or nighttime into twelve equal parts. Because the length of daylight (and nighttime) varies with the seasons, so too do the lengths of the seasonal hours. Equinoctial hours are of equal length on all days of the year and represent 1/24 of the time between successive noons.

8. The term Kufic refers to a calligraphic style consisting of stiff, angular, Arabic characters analogous to printed Roman characters.

9. The numbers in parentheses refer to catalog entries.

10. Neugebauer, "The Early History of the Astrolabe," page 240, quotes from Synesius (d. A.D. 412) to support the suggestion that Hipparchus invented the method of stereographic projection.

11. See note 3.

12. Several editions of the compendium, *Margarita Philosophica*, are known. The earliest of these, edited by Gregor Reisch was published in 1503.

13. For example, Abu-l-Ḥusayn ^{c}Abd ar-Raḥman ben Umar aṣ-Ṣufi (A.D. 903–986), *Kitāb al-^{c}amal bi-l-aṣṭurlāb.*

14. Al-Biruni's discussion of the construction and use of the astrolabe appears in his *Book of Instruction in the Elements of the Art of Astrology*, completed ca. A.H. 1020; especially pertinent are sections 324–346.

15. An effort has been made throughout this introductory essay to employ terminology familiar to the maker in describing his work.

16. The term *mashriq* is used throughout this essay to mean that portion of the Muslim world now referred to as the "Middle East."

17. Hejira dates inscribed on astrolabes made in the mashriq or the maghrib have been converted to A.D. dates (given in brackets) using the method described in Augustus de Morgan's *The Book of Almanacs.* Before 1585, the conversion involves the Julian calendar; after 1585, the Gregorian calendar.

18. The ^{c}*ankabūt* is shown opposite page 195b in Wright's translation of al-Biruni.

19. R.T. Gunther illustrates another example of Ja^{c}far's work in *The Astrolabes of the World*, page 130.

20. Henri Michel has pointed out in his *Traité*, (pages 135–141) that this convention makes possible the dating of astrolabes constructed before the period of calendar reform. The telling element is the date of the vernal equinox (Aries, 0°) which, in the Middle Ages, progressed backward through the month of March at the rate of about one day every 100 years. A comparison of vernal equinox days with inscribed dates on the pre-fifteenth century maghribi astrolabes in the collection leads to the following results:

CCA No.	*Aries 0°*	*Inscribed date*
3643	14 March	[illegible]
144	14.5 March	A.H. 704
4001	14.9 March	A.H. 621
2572	15 March	A.H. 483

21. These enduring elements include numerous counterchanges in the bar representing the equinoctial colure and a support for an equatorial arc flanked by Moorish arches.

22. This is the date of death of Hermann Contractus, author of what is believed to be the first European treatise on the astrolabe (see Gunther, *Astrolabes*).

23. The most accessible edition of Chaucer's treatise can

be found in Gunther's *Chaucer and Messahalla.*

24. The bibliography appended by Gunther to his *Astrolabes of the World* lists most known early works and reveals that many appeared in several editions.

25. The epoch of a table of astronomical parameters is the date for which it has been calculated. Since precession affects the values of these parameters in a predictable way, knowledge of a table's epoch enables its user to update it if necessary.

26. These are No. 304, with a vernal equinox coinciding with 11 March, and No. 186, with a vernal equinox at 10.5 March.

27. In Morley's "Description of a Planispheric Astrolabe Constructed for Shah Sultan Husain Safawi" (page 9), first published in 1856 (also reprinted by Gunther in his *Astrolabes of the World*), Morley observes that the designation of this single-latitude instrument is unique to Latin writers who call it "unius latitudinis aut elevationis polaris astrolabium."

28. The term *maghrib* is used throughout this essay to refer to Arab-occupied territory in North Africa and Spain.

29. The relevance of the cotangent scale in Arab lands is easily understood. It readily enables the user to determine the ratio between the height of a gnomon and the length of its shadow at any time of day. Such a ratio is a determinant of prayer-time in many Muslim sects. The scale would have no analogous European use. To a European maker or user the cotangent scale would appear to duplicate superfluously the scales of the shadow square.

30. Gunther describes an interesting maghribi exception to this "rule." On its rim, the 24 hours are marked by small dotted circles (*Astrolabes of the World*, page 290). Hartner suggests a reason for the absence of equal hour scales on Arab astrolabes when he explains that while the European way of counting equal hours from midday and midnight was known to Islamic astronomers it was never used in civil life ("Principle and Use of the Astrolabe," page 297).

31. The relevant figure (precisely, from MS Cambridge Dd. 3.53) is reproduced on page 6 of Gunther's *Chaucer and Messahalla on the Astrolabe.*

32. The Italian ascription is due to the evidence supplied by the several plates engraved for Italian cities: *Venetie*, *Neapolis*, *Castelli*, *Roma.*

33. See Gunther, No. 192, p. 341, and No. 247, p. 423.

34. CCA No. 2006 is not the only one that presents dating problems. In fact, the student of early scientific instruments must be alert constantly to the possibility that an object of study may have passed through a number of hands before being subjected to his scrutiny. Previous owners of scientific instruments may well be suspected of modifying an object to suit their needs. The separable parts of an astrolabe make it especially vulnerable to this type of modification. It is therefore risky to make any assumptions about the origins of unsigned parts of an astrolabe.

35. Gibbs, Henderson, and Price, in *A Computerized Checklist of Astrolabes* list 19 authentic (not fake) Arab instruments and 197 authentic European instruments made between 1499 and 1600.

36. See the plates accompanying the description of astrolabe No. 180 in Gunther, *The Astrolabes of the World.*

37. A portion of the comparative analysis section of this essay has been devoted to elucidation of these various scales.

38. For details see the section on plates, p. 54.

39. In his *Tabulae Directionum*, completed in 1467 (available in a 1972 edition), Regiomontanus proposed that the boundaries of the astrological houses be great circles running through the north and south points on the horizon and dividing the equator into 12 equal parts.

40. Regiomontanus mentions these two men as authors of systems of houses, which his own system is designed to replace. Alcabitus or al-Qabiṣi was an Iraqi astronomer who, about A.H. 950, composed an "Introduction to the Art of Astrology" in which he described houses bounded by great circles that coincided with the great circle approximations of the unequal hour lines. Regiomontanus' mention of Campanus of Novara (d. 1296) and his astrological houses (bounded by great circles that pass through the north and south points on the horizon and divide the prime vertical into 12 equal parts) established the latter astronomer as an authoritative astrologer. No specific astrological treatise can be attributed to him with certainty, however.

41. Hartman was born in Eggolsheim in 1489 and died in Nuremberg in 1564.

42. Relatively few astrolabes inscribed with Latin characters survive from this period. They include an instrument signed by Anthony Sneewins in 1661, now in the Musée des Arts et Métiers in Paris (Gunther, *The Astrolabes of the World*, page 402) and an instrument signed by P. Sevin in 1682, now in the Adler Planetarium in Chicago.

43. Michel has grouped the variable elements of astrolabe design into the following styles: Egyptian, Hispano-Moorish, Gothic, Renaissance, Persian, Indo-Persian, and Hindu.

44. The geographic qualifier *al-Yazdi* is not part of Mahdi's signature on either of these instruments. His association with the Persian city of Yazd is documented by signatures on other instruments (Gunther, *The Astrolabes of the World*, page 121) and by his collaboration with Muḥammad Muqim al-Yazdi (see L.A. Mayer, *Islamic Astrolabists and Their Works*, pages 70, 71).

45. In discussing this second instrument, Mayer (*Islamic Astrolabists and Their Works*, page 71) notes that the "character of the script and of the decoration differs from all his [Mahdi's] other signatures."

46. See Michel, *Traité de l'Astrolabe*, page 157.

47. The signature on each of these two instruments ends with the phrase *asṭurlābī hūmāyūnī Lāhōrī*; hence, the association with Lahore.

48. The pierced throne of Muḥammad Muqim's astrolabe is presently covered by two plates attached with rivets.

49. The use of dashed lines in the rim scale seems especially indicative of the Indo-Persian style.

50. The signature on this instrument reads: *ṣāḥib Qāsim ᶜAli asṭurlābī Qāᵓini.*

51. The family was first recognized by Gaston Wiet, who reported his conclusions in 1936 (*Bulletin de l'Institut Francais d'Archeologie Orientale*, Cairo, volume 36, pages 97–99). Wiet's work was extended in 1937 by Nabia Abbott and Syed Sulaiman Nadvi in articles in *Islamic Culture* (volume 11, pages 144–146; volume 11, pages 537–539).

52. An astrolabe signed by al-Hadad dated A.H. 975 [A.D. 1567], is reportedly preserved in the Library of Sir Salar Jung Bahadar of Hyderabad. An astrolabe bearing ᶜIsa's signature, dated A.H. 1013 [A.D. 1604], is preserved in the instrument collection of the Adler Planetarium, Chicago.

53. The collection of Qazi Obeiduᵓl-Bari in Calcutta preserves one of the few remaining astrolabes signed by Qaᵓim Muḥammad; the instrument is dated A.H. 1034 [A.D. 1624].

54. Dated astrolabes by Muḥammad Mahdi, none of them in the collection, indicate that he worked between A.H. 1059 [A.D. 1649] and A.H. 1070 [1659] (see Mayer, *Islamic Astrolabists*, page 70.) The signature Muḥammad Amin appears on two instruments dated A.H. 1086 [1675] and A.H. 1097 [1685]. The chronology undermines the possibility of a father-son relationship involving these two. The date of the work of Muḥammad Amin ben Mirza Khan makes it probable that if such a relationship existed, he is the father.

55. Muḥammad ben Aḥmad's name appears on some 20 instruments made between A.D. 1715 and 1737. Two of these are preserved in the collection of instruments at the Adler Planetarium, Chicago. Only three of Ḥasan's instruments (all astrolabes created between A.D. 1685 and 1694) are preserved.

56. No European instruments inscribed with explicit eighteenth century dates survived to be included in Gibbs, Henderson, and Price's *A Computerized Checklist of Astrolabes.*

57. The study of Gingerich, King, and Saliba, "The ᶜAbd al-Aᵓimma Astrolabe Forgeries" shows that dates only rarely appear on authentic ᶜAbd al-Aᵓimma instruments and then only in dedications (see their table 1, page 189.)

58. ᶜAbd al-Aᵓimma also decorated at least one instrument for Muḥammad Amin's father, Muḥammad Ṭahir; Ṭahir's astrolabe is in the City Art Museum in St. Louis. He collaborated with Muḥammad Khalil on several instruments (four are preserved in the Museum of History of Science, Oxford). His name appears with that of ᶜAbd al-ᶜAli on one astrolabe (also in the Museum of the History of Science, Oxford). These other astrolabists can be considered to be the most important members of ᶜAbd al-Aᵓimma's "school."

59. ᶜAli's name appears on 12 surviving instruments made between A.H. 1203 [1788] and A.H. 1208 [1793]. The example in the collection is numbered "the fifteenth." This practise of numbering each instrument calls to mind the similar practise of the European astrolabist, Georg Hartmann. There is a major difference, however, in that only the body of ᶜAli's instrument is numbered.

60. See, for example, CCA No. 87, signed by Ḍiyaᵓ al-Din Muhammad ben Qaᵓim Muḥammad.

61. See Derek Price's article "An International Checklist of Astrolabes" for a description of the method used.

62. The one curious stylistic anomaly evident in this example is the rim scale. It neither incorporates dashed lines nor consists of four 90° arcs.

63. Ṣadiq's name, preceded by the term "ṣanaᶜahu," appears in a cartouche on the back of this instrument. The date, "1216," and the name "ᶜAbd al-Karim" appear within the shadow squares.

64. See the commentary on gazetteers, p. 26.

65. The only other known astrolabe signed by Muḥammad Akbar is preserved in the Whipple Museum, Cambridge. Its diameter is less than half that of the example of his work in this collection.

66. This instrument is not the only example in the collection inscribed in two languages. Astrolabe No. 2572 consists of a body and plates inscribed in Arabic and a rete inscribed in Hebrew. The names of maker and owner of the Sanskrit astrolabe were suggested by David Pingree, who kindly provided a translation.

67. Translation, from Gunther, *Chaucer and Messahalla on the Astrolabe*, p. 5.

68. The term *Naskhī* refers to a calligraphic style consisting of rounded, cursive, Arabic characters as distinct from the angular Kufic script.

69. For a discussion of the ancient origins and use of these wind scales see A. Rehm's "Griechische Windrosen."

70. The dials are identified in Derek Price's article, "Portable Sundials in Antiquity, Including an Account of a New Example from Aphrodisias."

71. O. Neugebauer emphasizes the importance of Ptolemy's tables in his *History of Ancient Mathematical Astronomy*, page 969. The earliest known edition of the tables was prepared by Theon in the fourth century A.D. The identity of the primary point of longitude in Ptolemy's geographical coordinate system remains uncertain. It could be any group of islands off the African coast, e.g., Canary or Madeira.

72. E.S. Kennedy describes a number of *zījes* in his "Survey of Islamic Astronomical Tables."

73. For example, access to Sedillot's published translation of Ulugh Beg's list of important cities led William H. Morley to identify this list as the source of the gazetteer inscribed on the astrolabe made for Shah Sultan Husain in A.D. 1712. Ulugh Beg's *zīj* was written about A.D. 1440. It could well have been the standard reference for all later astrolabes.

74. Sectors containing Mecca and Medina are adjacent (in a counterclockwise direction) to the sector containing the titles of the various components of the circular table.

75. This characteristic can be considered another indication of Qasim ᶜAli's Indo-Persian affinities. His gazetteer does not contain geographic parameters relating to Mecca.

76. The sequence is not based on increasing latitude or longitude or on any progression of the other parameters in

the scale. It does, however, seem to follow well-traveled routes between cities in the Muslim world.

77. The equivalence between *farsakh* and degree of arc varies from geographer to geographer anywhere from 25 *farsakhs* to 18$\frac{1}{3}$ *farsakhs* per degree.

78. The use of the term "feet" in this context has origins in the Greek practise of measuring the length of the shadow cast by a human gnomon by setting one foot in front of another. The height of the average human gnomon was seven human "feet," leading to the practise of dividing any given gnomon into sevenths and using the term "feet" to refer to the divisions. The use of the term "fingers" to refer to the 12 divisions of a gnomon of given length has its origin in the Babylonian observation that a finger held at arm's length obscured 1/12 of a degree of the night sky.

79. O. Neugebauer provides a detailed description of this tradition in of *A History of Ancient Mathematical Astronomy*, pages 736–748.

80. See Hartner, "The Principle and Use of the Astrolabe," page 302, figure 850.

81. See Michel, *Traité*, page 90.

82. Ptolemy compares this Egyptian system of terms with a Babylonian system in the *Tetrabiblos*, volume 1, page 20.

83. See al-Biruni, *Book of Instruction*, page 263.

84. For a discussion of how each group was formed, see Ptolemy, *Tetrabiblos*, volume 1, page 18.

85. See Morley's "Description of a Planispheric Astrolabe," page 19.

86. Michel explains this relationship in his *Traité*, pages 83, 84.

87. See Michel, *Traité*, page 22.

88. See Michel, *Traité*, pages 127, 128.

89. See de Roias, *Commentarium in Astrolabium*.

90. See al-Biruni, *Book of Instruction*, p. 197.

91. The term *abdjad* is used to refer to numerals formed from letters of the Arabic alphabet (e.g., ʾ = 1, b = 2, j = 3, d = 4).

92. See Hartner, "Principle and Use," page 297.

93. See Wright's translation of al-Biruni, *Book of Instruction*, pages 205, 206.

94. See Hartner, "Principle and Use," page 299.

95. See Ptolemy, "Planisphaerium" (in the *Opera*), sections 8 and 9.

96. See Emmanuel Poulle, "La fabrication des astrolabes au Moyen Age," pages 117–128.

97. See the section on Hermannus Contractus in Gunther's *Astrolabes*, pages 406, 407. Also relevant are Reisch's *Margarita Philosofica*; Gunther's *Chaucer and Messahalla*, pages 1057, 1058; Stöffler, pages 33, 34, and 39–41; and Egnazio Danti, pages 162, 163.

98. See Poulle, "La fabrication des astrolabes au Moyen Age," pages 124, 125.

99. See Gunther, *Chaucer and Messahalla on the Astrolabe*, page 171.

100. See al-Biruni, *Book of Instruction*, page 200.

101. See Price on "Portable Sundials," pages 253–262.

102. See Gunther, *Chaucer and Messahalla on the Astrolabe*, page 174.

103. For a discussion of other works by ʿAbd al-Aʾimma, see Gingerich, King, and Saliba's 1972 article on astrolabe forgeries, pages 188–198.

104. All dates are from Gibbs, Henderson, and Price, *A Computerized Checklist of Astrolabes*.

105. See L.A. Mayer, *Islamic Astrolabists and their Work*, plate 13.

106. See Stöffler, pages 33, 34, and 39–41.

107. See Mayer, *Islamic Astrolabists*, page 14.

108. See Mayer, *Ibid.*, page 42.

109. See Mayer, *Ibid.*, page 50.

110. See Gunther, *Astrolabes of the World*, page 302.

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